ETSO-C97
Date : 24.10.03

European Aviation Safety Agency

European Technical Standard Order

Subject: LITHIUM SULFUR DIOXIDE BATTERIES

1 - Applicability

This ETSO gives the requirements which lithium sulfur dioxide batteries that are manufactured on or after the date of this ETSO must meet in order to be identified with the applicable ETSO marking.

2 - Procedures

2.1 - General

Procedures are detailed in CS-ETSO Subpart A.

2.2 - Specific

None.

3 - Technical Conditions

3.1 - Basic

3.1.1 - Minimum Performance Standard

Standards set forth in the attached Federal Aviation Administration Standard „Lithium Sulfur Dioxide Batteries.

3.1.2 - Environmental Standard

As stated in the Federal Aviation Administration Standard.

3.1.3 – Computer Software

None

3.2 - Specific

None

4 - Marking

4.1 - General

Marking is detailed in CS-ETSO Subpart A paragraph 1.2; in addition to the markings required by this paragraph, each battery must be marked with the month and year of manufacture and the date on which it must be replaced. In addition, each cell and battery must be marked with the phrase: „$LiSO_2$ BATTERY CAUTION: PRESSURIZED CONTENTS; NEVER RECHARGE, SHORT CIRCUIT OR EXPOSE TO TEMPERATURES ABOVE 70°C“.

4.2 - Specific

None.

5 - Availability of Referenced Document

See CS-ETSO Subpart A paragraph 3.

FEDERAL AVIATION ADMINISTRATION STANDARD
LITHIUM SULFUR DIOXIDE BATTERIES

1.0 General.

1.1 This standard applies to cells and batteries of a nonaguous $LiSO_2$ type. Batteries may consist of a single cell, cells connected in series or in parallel, or both, to obtain the necessary output for the intended application. Definitions for terms used in this standard are set forth in Appendix A of this standard.

2.0 Minimum Performance Under Standard Conditions.

2.1 *Cell Isolation.* Cells in a multi-cell battery or packs of more than one battery may not be connected in parallel unless provisions are made to prevent individual cells from being exposed to charging voltages greater than the cell's nominal open circuit voltage. When five or more cells are reconnected in series, each cell must be protected by a shunt diode.

2.2 *Cell connection.* All electrical connections between cells in a battery must be soldered, welded, or brazed in accordance with an approved process specification.

2.3 *Safety Relief*

2.3.1 *Safety Relief Mechanism.* Each cell used in the battery must incorporate a safety relief mechanism that will relieve internal pressure at a value and rate which will preclude venting violently, or explosion. The safety relief must operate at a temperature below 130°C in accordance with §T-l of Appendix B of this standard.

2.3.2 *Discharge Materials.* If a cell vents during any of the tests required by §§3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, and 3.10, the data requirements of §37.209 (d)(2) must be met.

2.4 *Encapsulation.* Encapsulation of the battery may not be used unless it is demonstrated, in accordance with §§T-2 and T-3 of Appendix B of this standard, that encapsulation does not inhibit the functioning of the safety release mechanism or cause the battery to overheat.

2.5 *Seal.* Each cell must be hermetically sealed. The seal must be tested in accordance with §T-4 of Appendix B of this standard. The difference in the weight of the cell before and after this test must be less than 50 milligrams.

2.6 *Current Limiting Protection.* The battery must have a current limiting device. This device must limit the current that can be drawn from the battery to a value lower than that which it was subjected to in §§3.8, 3.9, and 3.10 of this standard, and must be an integral part of the battery and not susceptible to shorting or any failure causing the device to be bypassed.

2.7 *Useful life.* The useful life of the battery may not exceed 4 years unless demonstrated. The useful life must be demonstrated at a minimum temperature of 40°C. When tested at periods in excess of 4 years, the battery must retain 80 percent of its ampere-hour capacity as demonstrated in accordance with §T-5 of Appendix B of this standard, and meet the requirements of §§2.9, 2.10, and all sections under §3.0 of this standard.

2.8 *Examination of Product.* When required, subsequent to a test required by §3.0 of this standard, each of the cells must be visually examined. Special emphasis must be placed on observing signs of leakage and overall appearance of the safety relief feature.

2.9 *Open Circuit Voltage.* Open circuit voltage of the battery must be measured and be within ±5 percent of its specified value, and the polarity must be correct.

2.10 *Capacity.* The variation in battery capacity may not vary more than ±10 percent when compared with the capacity as demonstrated in accordance with §T-6 of Appendix B of this standard.

3.0 Minimum Performance Standards Under Environmental Conditions.

3.1 *General.* Except as provided in §§3.6, 3.7, 3.8, 3.9, and 3.10 of this standard, the design of the battery must be such that subsequent to the application of the specified tests, no condition may exist that would be detrimental to the continued performance of the battery. The same battery must be used for the following tests and these tests must be performed in this order: §§3.2, 3.3, 3.4, 3.5, and 3.6.

3.2 *Shock Test.* The battery must be secured to a shock table by a mechanically secure device. The shock test machine must be capable of imparting to the battery a series of calibrated shock impulses. The shock impulse waveform must be a half sine pulse whose distortion at any point on the waveform may not be greater than 15 percent of the peak value of the shock pulse. For the purposes of this section, duration of the shock impulse is specified with reference to the zero points of the half sine wave, and shock forces are specified in terms of peak amplitude G values. The shock impulse must be measured using a calibrated accelerometer and associated instrumentation having a 3dB response over a range of at least 5 to 250 Hertz. The shock test must be conducted as follows:

(a) Mount the battery on the shock test machine in such a manner that it can be subjected to shock impulses in each direction successively along the three mutually orthogonal axes of the battery.

(b) Apply a l00G shock impulse of duration 23±2 milliseconds to the battery in a direction coincident with the first orthogonal axis.

(c) Reset the activation mechanism.

(d) Repeat the procedures specified in §§3-2(b) and (c) applying an impulse shock in the remaining 5 axial directions.

3.3 *Vibration Test.* The battery must be secured to a vibration table so that sinusoidal vibratory motion can be exerted parallel to one of the three major orthogonal axes of the battery. The battery must be affixed to the vibration table by the means specified by the equipment manufacturer for service installations. The vibration frequency must be varied at a rate not to exceed 1.0 octave per minute. The vibration must exhibit a constant total excursion of

2.5mm from 5 Hertz to the frequency at which an acceleration of 7G (zero-to-peak) is reached and from that frequency to 2,000 Hertz at a constant acceleration of 7G. Continue the vibration for a minimum of 1 hour. The tests described in this section must be repeated with the vibratory motion being applied along each of the other major axes of the cell.

3.4 *Temperature Cycle Test.* The battery must be subjected to a temperature not greater than -65°C for a period of 20 hours. The test chamber temperature must then be raised at a rate of 5° ± 2°C per minute to a temperature of at least +71°C, and this temperature maintained for a period of 4 hours. After the 4-hour period, the test chamber temperature must be returned, at a rate of 5° ± 2°C per minute, to a temperature not greater than -65°C, and this temperature must be maintained for 20 hours. The temperature cycle must be repeated 5 times. After completion of the temperature cycle, the battery must be returned to room temperature.

3.5 *Altitude Test.* The battery must be stored for 6 hours at an atmospheric pressure corresponding to an altitude of 15,000 meters at 24° ± 4°C. The pressure must then be increased to sea level pressure.

3.6 *Immersion Test – Salt Water.* After being immersed in salt water (3.5 ± 0.1 percent sodium chloride), with terminals insulated, for a period of at least 15 hours, the battery must be tested for leakage in accordance with §T-4 of Appendix B of this standard, and meet the requirements of §§2.8, 2.9, and 2.10 of this standard.

3.7 *High Temperature Battery Capacity Test.* After 30 days of storage at a temperature of 71° ± 2°C, the battery must be returned to room temperature and must be capable of delivering 90 percent of its rated capacity with no more than ± 10 percent variation in cell capacity. The test must be performed in accordance with §T-6 of Appendix B of this standard.

3.8 *Reverse Discharge Test.* The cell must not be fuse protected. The cell must be discharged in series with an external power supply at a current equal to that of the rating of the fuse used in the battery at a temperature of 24° ± 3°C. The discharge must be maintained for a time corresponding to the rated capacity of the battery that the cell will be used in or until the cell has vented. The cell condition must be monitored for 24 hours after termination of reverse discharge.

3.9 *Forced Discharge Test.* The battery must be operative and have the fuse removed for purposes of this test. The test must be conducted on (1) a battery that has not been discharged, and (2) a battery that has completed the high temperature battery capacity test of §3.7. A battery must be forced discharged at a current load equal to that of the rating of the fuse used in the battery at a temperature not greater than -20°C isothermally for a period corresponding to the rated capacity of the battery. The battery condition must be monitored for 24 hours after the rated capacity of the battery has been reached.

3.10 *Total discharge Test.* The battery must be operative and have the fuse removed for purposes of this test. The battery must be discharged at a temperature of 24° ± 3°C at a current level equal to that of the rating of the fuse used in the battery for a period corresponding to the rated capacity of the battery. Immediately thereafter, a direct short must be placed and left across the battery terminals. The battery condition must be monitored for 24 hours after the direct short has been applied.

APPENDIX A

The following definitions of terms are applicable to the Lithium Sulfur Dioxide Batteries Standard.

1.0 Definitions. For purposes of this standard, the following definitions apply:

„Battery“ means an electrical energy source made up of one or more cells, arranged in electrical series or parallel or in a series-parallel combinations.

„Capacity“ means the total amount of electrical energy, measured in ampere hours, that a cell can generate.

„Cell“ means an individual electrochemical unit.

„Hermetic sealed cells“ means that each cell is sealed in such a manner that over the useful life of the cell there is no loss of gaseous or solid material from the cell.

„Venting“ means the controlled release of the electrolyte or any chemical reactant products, or both, from a cell.

„Venting violently“ means the rapid uncontrolled discharge of either harmful gases or liquid, or both, from a cell accompanied by the generation of heat.

APPENDIX B

The following test procedures give details for demonstrating that the requirements of the Lithium Sulfur Dioxide Batteries Standard are met.

T-l Verification of safety relief mechanism (§2.3.1).

Equipment Required:

Calibrated iron constantan thermocouple, accurate to within ± l° C.

Electric heating tape.

Recording potentiometer.

Test Procedure:

a. Attach a thermocouple to the surface of the metal cell case under test and attach the thermocouple to the recording potentiometer.

b. Wrap the circumference of the cell, not covering the ends, with the electric heating tape.

c. Increase the temperature of the cell at a linear rate of 10° ± 3°C per minute.

d. Continuously monitor the temperature of the cell case and record the temperature at which the cell(s) vent.

T-2 Operation of safety relief in encapsulating material (§2.4).

a. Expose the battery to environmental conditions which will cause the battery to vent (e.g., high temperature or direct short with the current limiting device inoperative).

b. The operation of the safety relief mechanisms and the encapsulation should be observed.

c. Determine that the encapsulation material does not cause the battery to vent in a manner different than that of the cell tested in §T-1.

T-3 Heat transfer properties of the encapsulation material (§2.4).

Equipment Required:

Two calibrated thermocouples accurate to ± 1° C. Two recording potentiometers.

Test Procedure:

a. Attach a load to an encapsulated battery with the fuse removed which will draw a current equal to the ampere rating of the fuse used in the battery.

b. Attach a load to an identical battery without encapsulation and with the fuse removed which will draw a current equal to the ampere rating of the fuse used in the battery.

c. Continuously monitor the temperature of both batteries. The room ambient temperature should be 24° ± 3° C.

d. Continue the test until the ampere hour rating of the cell is reached.

T-4 Hermetic Seal test (§2.5).

Equipment Required

Temperature controlled oven.

Scale (accurate to 1 milligram).

Test Procedure:

a. Weigh each cell under test.

b. Place each cell in the temperature controlled oven.

c. Raise the temperature to 71°C.

d. Maintain this temperature for 30 days.

e. Lower the temperature to ambient.

f. Remove the cells and weigh each cell.

g. Compare the weight of each cell with the weight before the test.

T-5 Useful life (§2.7).

Equipment Required:

Temperature controlled oven.

Test Procedure:

a Place each battery in the temperature controlled oven, seals pointed down so that the seal is covered by the electrolyte.

b. Raise the temperature to at least 40°C.

c. Maintain this temperature for 4 years plus the additional time for which useful life is desired to be demonstrated.

d. Lower the temperature and remove each battery.

e. Measure the remaining capacity of the cell in accordance with §T-6 of this Appendix.

T-6 Battery Capacity (§2.10).

Equipment Required:

Resistive load.

Data recorder.

Digital printer.

Digital voltmeter.

Test Procedure:

a. Attach a resistive load to the battery under test which will initially draw a current equivalent to the value of the fuse used in the battery in which the cell under test is to be used.

b. Monitor the voltage time until the end-voltage of the battery reaches 0.5 volts.

c. Calculate the cell capacity using the timed averaged voltage method. The formula for this method is

$$\overline{V} = \frac{1}{tco} \sum_{i=1}^{n-1} \frac{\left(V_i + V_{i+1}\right)}{2} \left(t_{i+1} - t_i\right)$$

$$AH = \overline{V} \; \frac{tco}{R_L}$$

where:

V = Time averaged voltage

tco = Elapsed discharge time to cutoff in hours

Vi = Voltage at time t_i

V_{i+1} = Voltage at time t_{i+1}

t_i = Time in hours at which V_i was measured

t_{i+1} = Time in hours at which V_{i+1} was measured

AH = Discharged capacity

R_L = Load resistance in ohms