

Examining Vibration Endurance Tests And Complying With

BATSO 01 (Battery Safety Organization)

In Order To Achieve International Certified Safety In The Supply And Value Chain
Secondary Lithium Batteries



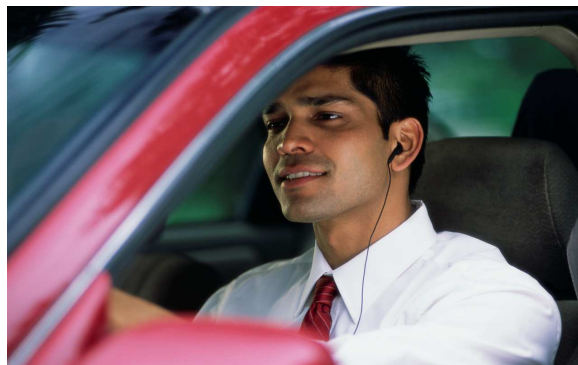
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www.batso.org / www.li-tec.de



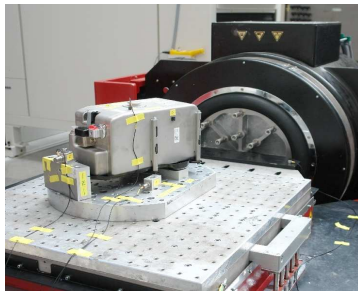
Examining Vibration endurance tests

- Introduction
- Examples
- BATSO



The new EV.age is born!

- Li-ion based battery systems are an efficient alternative energy storage system for electrically propelled vehicles in future.
- The requirements for Li-ion based battery systems to be used as power source for the propulsion of electric road vehicles are significantly different to those batteries used for consumer electronics or stationary usage.



HIGH LEVELS OF SAFETY WITH LARGE RECHARGEABLE LITHIUM BATTERIES...and what's about Reliability?

- Electric vehicles are particularly susceptible to environmental extremes.
- Vibration, Moisture, corrosion, and temperature extremes which are common place for fossil fueled vehicles, can significantly degrade electric vehicle performance.



EV BATTERIES...and what`s about Reliability

- Electric vehicle designers and developers are faced with a wide range of technological challenges in order to produce marketable, reliable products.
- Reliability tests are representative of the needs of the marketplace, reducing manufacturing risk and increasing customer satisfaction.



Shock and Vibration

- There is wide range of test courses which allow simulation of world wide duty cycle conditions. For electric vehicles, it is critical to identify inputs to which the vehicle system may be sensitive and develop corrective actions before significant test mileage has been accumulated.
- A range of test courses which provide high frequency (washboard, Belgian Block, Heidelauf etc.) and low frequency (torsional, pothole, grades, etc.) inputs to the vehicle system. Test scenarios are developed to provide accelerated inputs or cycles which simply represent the day-to-day environment that electric vehicle operators will encounter.



Li Ion Battery Development Goals...

(not EV!)

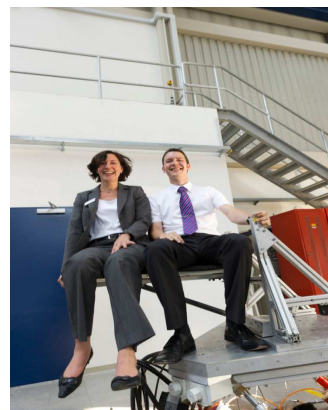
Batteries are required to function in extreme vibration environments

- Up to 90 Grms in some positions
- random vibration



Reliability is indispensable...

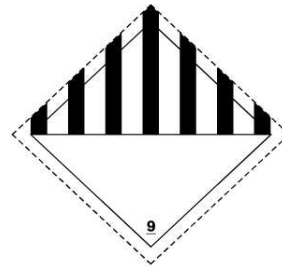
- Lithium-ion batteries are estimated to be one of the most promising secondary batteries for the propulsion of electric vehicles.
- In the light of rapidly diffusing hybrid electric vehicles and emerging battery and plug-in hybrid electric vehicles, a standard method for testing reliability and abuse requirements of lithium-ion batteries is indispensable for securing a basic level of safety and obtaining essential data for the design of vehicle systems and battery packs.



UN-T

Required UN-Transportation Tests on Li-Ion Batteries:

- UN-Test # 1: Altitude simulation
- UN-Test # 2: Thermal test
- UN-Test # 3: Vibration
- UN-Test # 4: Shock
- UN-Test # 5: External short circuit
- UN-Test # 7: Overcharge



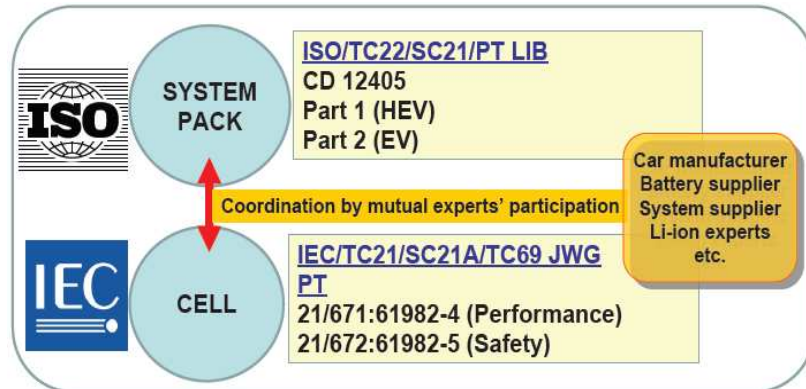
UN Test # 3: Vibration Test

This test simulates transport vibration

Parameters:

Waveform:	sinusoidal	
Frequency range:	7 – 200 Hz	
Profile:	Frequency	Amplitude
	7 – 18 Hz	1 g
	18 – 50 Hz	1.6 mm _{pp}
	50 – 200 Hz	8 g
Sweep velocity:	0.645 Oct. / Min.	
Number of sweeps:	24 (12 up and 12 down)	
Total exposure time per Axis:	3 hrs	
Axis:	X; Y; Z	
Number of test units:	16	
Test condition:	Ambient temperature	

System Pack vs. Cell : Vibration



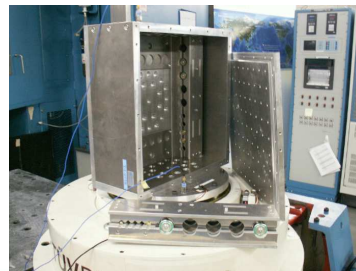
note: **IEC 62660-1CDV (formerly IEC 61982-4)**

Standards for Vehicle Industry in the People's Republic of China
 QC/T 743-2006, UL 2271, IEC 61959, IEC 600864, Mercedes Benz
 MBN 10305-2, BATSO-O1... (source ISO, IEC, ZVEI Germany)

UN 38.3 / BATSO / VDE V 0510-11 / DIN EN 62281 / DIN IEC 61982

Prüfung:	UN 38.3	BATSO	DIN EN 62281	DIN IEC 61982-5	VDE V 0510-11
Schwingen	ja (Sinus)	ja (Sinus)	ja (Sinus)	ja (Random)	ja (Random)
Schwingen	8 Batt.	Sinus 7-200 Hz. 3 Std. pro Achse	Sinus 7-200 Hz. 3 Std. pro Achse	10 Hz. - 1kHz. 8Std. Gem. IEC 60068-2-64	Nach IEC 60068- 2-64 Random Tab. B1

- EN 8 batteries,
- VDE V 0510-11, 2 batteries
- BATSO 2 batteries or modules



IEC 62660-2 CDV



6.1 Mechanical test

6.1.1 Vibration

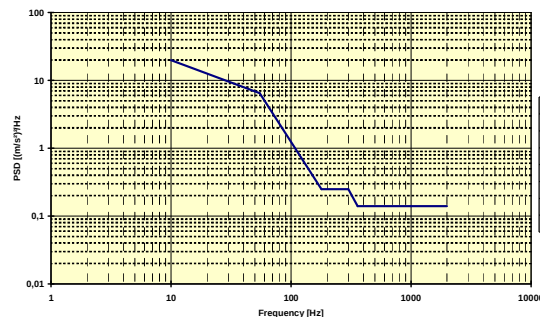
- This test is performed to characterize cell responses to vibration assumed in the use of vehicle.

6.1.1.1 Test

- Adjust the SOC of cell to 100 % for BEV application, and to 80 % for HEV application in accordance with 5.3.
- Perform the test referring to IEC 60068-2-64 random vibration. Use test duration of 8 h for each plane of the test cell.

IEC 62660-2 CDV

- The r.m.s. acceleration value shall be $27,8 \text{ m/s}^2$. The power spectrum density (PSD) vs. frequency is shown in Figure 2 and Table 2. The maximum frequency shall be 2000 Hz.



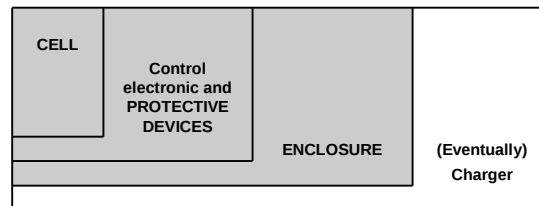
Frequency [Hz]	PSD [(m/s²)/Hz]
10	20
55	6,5
180	0,25
300	0,25
360	0,14
1000	0,14
2000	0,14

The goal of BATSO

- Is to increase safety of existing and new battery technologies.

Testing methods of this manual will support a fast and economic way of battery testing.

The BATSO test seal will help all parties involved in the Light Electric Vehicle business to find and utilize safer batteries.



BATSO Vibration endurance

- Chapter 5 , 5.1 electrical tests, **5.1.3 Vibration endurance**
- Vibration endurance (test options 1 and 2)
- *Purpose* This test simulates vibration as experienced during the operation of LEV.
- While vibrated, each FULLY CHARGED BATTERY is to be discharged according to the manufacturer's recommended minimum discharge voltage at the manufacturer's recommended maximum continuous discharge current.



Category	Sub-clause	Test item	BATSO 01 - Test option 1				BATSO 01 - Test option 2	
			Number of FRESH samples at first CYCLE		Number of samples after 50 CYCLES		Number of FRESH samples at first CYCLE, FC	Number of samples after 50 CYCLES, FC
			FC	FD	FC	FD	FC	FC
Electrical	5.1.1 a)	Overcharge	3	-	3	-	3	3
	5.1.1 b)		4	-	4	-	-	-
	5.1.2 a)	External SHORT CIRCUIT	3	-	3	-	3	3
	5.1.2 b)		4	4	4	4	-	-
	5.1.3 a)	Vibration endurance	3	-	3	-	3	3
	5.1.3 b)		4	4	4	4	-	-
	5.1.4	Partial SHORT CIRCUIT	3	-	3	-	3	3
Mechanical	5.2.1	Crush	2	-	2	-	2	2
	5.2.2	Shock	4	4	4	4	3	3
	5.2.3	Drop	3	-	3	-	3	3
Environmental	5.3.1	Low pressure	4	4	4	4	3	3
	5.3.2	Thermal	4	4	4	4	3	3

BATSO Vibration endurance I

- The vibration shall have a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular directions. One of the directions of vibration must be perpendicular to the terminal face.
- The logarithmic frequency sweep is as follows: from 7 Hz peak acceleration of 1 gn is maintained until 18 Hz is reached. The amplitude is then maintained at 0.8 mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 8 gn occurs (approximately 50 Hz). A peak acceleration of 8 gn is then maintained until the frequency is increased to 200 Hz.

NOTE – Symbol “gn” stands for standard acceleration of gravity (9.81 m/s²).



5.1.3 b) Vibration (test option 1) & Criteria

- See subclause 38.3.4.3 of *UN Recommendations on the Transport of Dangerous Goods* -
- *Manual of Test and Criteria*, (Test 3, "Vibration").

Criteria

- No mass loss & leakage, no venting, no disassembly, no fire, no rupture. And if the open circuit voltage after testing is not less than 90% of ist voltage immediately prior to this procedure (not fully discharged batteries or cells)



5.1.3 a) BATSO Criteria

- Vibration endurance
- ND, NF, NL, NR, NV
- ND, NF, NL, NR, NV
- Additional criteria:

The open circuit voltage of each BATTERY after testing is not less than 90 %

of its voltage immediately prior to testing.

- List of abbreviations:
- ND: No disassembly
- NF: No fire
- NL: No leakage
- NR: No rupture
- NV: No venting
- OCV: Open circuit voltage



No disassembly

No venting or rupturing occurred where solid parts of the battery have penetrated a wire mesh screen (annealed aluminium wire with a diameter of 0.25 mm and a grid density of 6 to 7 wires per cm) placed 25 cm away from the battery.

NOTE – In other publications the term explosion is used in the same meaning.

No fire

No emission of flames from a battery.

NOTE – Smoke is not considered as fire.



No leakage

No visible escape of liquid electrolyte. The mass loss of the BATTERY shall not exceed 0.1 % calculated as following:

$$\Delta m = \frac{m_1 - m_2}{m_1} \times 100\%$$

where

m_1 is the mass before the test

m_2 is the mass after the test

NOTE 3 – Sample tested in orientation(s) as described by the manufacturer.

NOTE 4 – Leakage is evidenced by liquid or condensed electrolyte composition external to the battery.



No rupture No venting

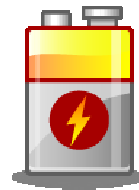
- **No rupture**
- No mechanical failure of a BATTERY case induced by an internal or external cause, resulting in expulsion of gas or spillage of liquids but not ejection of solid materials. Furthermore, the BATTERY shall not allow the test finger (see Annex E) to enter the case for 10 mm or more with a force of $30\text{ N} \pm 3\text{ N}$ applied over a period of 5 s.
- **No venting**
- No release of excessive internal pressure from a BATTERY in a manner intended by design to preclude rupture or explosion

Summary A

- Reliability & Safety in transport & application is most essential and prerequisite for market access
- BATSO = up to modules/batteries in low voltage area including certified and transparent UN38.3 T-tests registration and follow up service
- Safety LIB = tests+ highest state of the art QMS, Quality and lot testing in production + state of the art engineering on module & battery level
- Concept, structural safety due to location of the battery in an EV, an standard method for testing reliability and abuse requirements of lithium-ion batteries is indispensable for securing a basic level of safety and obtaining essential data
- Define high safety reserves for real crash accidents,

Summary B

- Criteria No thermal runaway in the event of crash, No explosion/rupture or flying parts
- BATSO suitable for LEV application and HEV up to several KW but, indeed
- Other actual applicable standard for EV Li-Ion battery like SANDIA, SAEJ2464 and criteria Eucar hazard level:
 - No correlation between crash force and battery weight,
 - Classification of risk potential...
- Amendments, new standards will be launched soon,



Thank You!
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Annex

EV Li-ion Battery Forum 2010 C* 2010 Tim Schäfer BATSO

Icons: battery, car, 27

BATSO – Testing and certification of Ion- batteries

- The international project for certified safety in the supply chain and value chain,
- BATSO (Battery Safety Organization), marks a new international Benchmark and offers transparency regarding the marking of Lithium-Ion batteries on a global scale.
- Compliance certificates can be downloaded from the Internet.
- New: Marking for batteries complying with UN-T (also modules, assemblies... could be covered according to new v. 5 of UN 38.3 manual) and BATSO 01.
- Note: press release

„UN 3480 Lithium-Ion Batteries - A new common standard for safety and transparence BATSO & TUVdotCOM mark for Lithium-Ion batteries“

EV Li-ion Battery Forum 2010 C* 2010 Tim Schäfer BATSO

Icons: battery, car, 28

Reference

CENELEC	European Committee for Electrotechnical Standardisation
IEC	International Electrotechnical Commission
ISO	International Standard Organisation
ANSI	American National Standard Institut
SAE	Standards of Automotive Engineering
JBA	Japan Battery Association
BATSO	Batterie Safety Organisation

Reliability, Abuse, Safety,...

No clear separation between Reliability, Safety and Abuse Tests

Attempt of definition:

Reliability tests: Simulating normal operating conditions
e.g. - vibrations , temperature changes (leads to dewing)

Safety tests: Simulating abnormal operating conditions
e.g. – overcharge, overdischarge

Abuse tests: Simulating improper „operating conditions“
e.g. – penetration, fire etc.

General speaking: **SAFETY** included Reliability, Safety and Abuse

(Source FCBAT/Ulm Prof. J. Garche)

Standards I

- IEC 62660-1 CDV (formerly IEC 61982-4)

Sekundär Batterien für den Antrieb von elektrischen
Straßenfahrzeugen

Teil 5: Prüfung des Leistungsverhaltens von Lithium Ionen Zellen

- IEC 62660-2 CDV (formerly IEC 61982-5)

Sekundär Batterien für den Antrieb von elektrischen
Straßenfahrzeugen

Teil 5: Zuverlässigkeit und Missbrauchs-Prüfungen für Lithium
Ionen
Zellen

Standards II

ISO 12405-1 DIS

- Electrically propelled road vehicles – Test specification for lithium-ion traction battery systems Part 1: **High Power** applications
- Typical application: **BEV** Battery Electro Vehicle and **PHEV** Plugin Hybrid Electro Vehicles

ISO 12405-2 WD

- Electrically propelled road vehicles – Test specification for lithium-ion traction battery systems Part 1: **High Energy** applications
- Typical applications: BEV Battery Electro Vehicles and PHEV Plugin Hybrid Electro Vehicles



USCAR, USABC, Freedomcar, SANDIA, EUCAR

- | | |
|-------------------|---|
| USCAR | - <u>U</u> nited <u>S</u> tates <u>C</u> ouncil for <u>A</u> utomotive <u>R</u> esearch
http://www.uscar.org/quest/index.php |
| USABC | - United States Advanced Battery Consortium
http://www.uscar.org/view_team.php?teams_id=12 |
| FreedomCAR | - Freedom symbolisiert die Unabhängigkeit; CAR steht für <u>C</u> ooperative <u>A</u> utomotive <u>R</u> esearch
http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/index.html |
| SANDIA | - Sandia National Laboratories
http://www.sandia.gov/ |
| EUCAR | - <u>E</u> uropean <u>C</u> ouncil for <u>A</u> utomotive <u>R</u> & <u>D</u>
http://www.eucar.be/organisation |

Global Market & Trends Li-Ion Batteries in LEV /



The emerging world market for large-format, secondary lithium batteries consisting of Lithium-ion (Li-ion) and lithium-ion polymer (Li-ion poly) is booming, as this chemistry offers improved features compared to the traditional battery chemistries

Criteria are fulfilled by Li-ion and Li-ion polymer batteries since they provide high-energy capacities and, hence, longer running times, are lightweight and of a compact size and also safe (in high quality and tested: BATSO !

