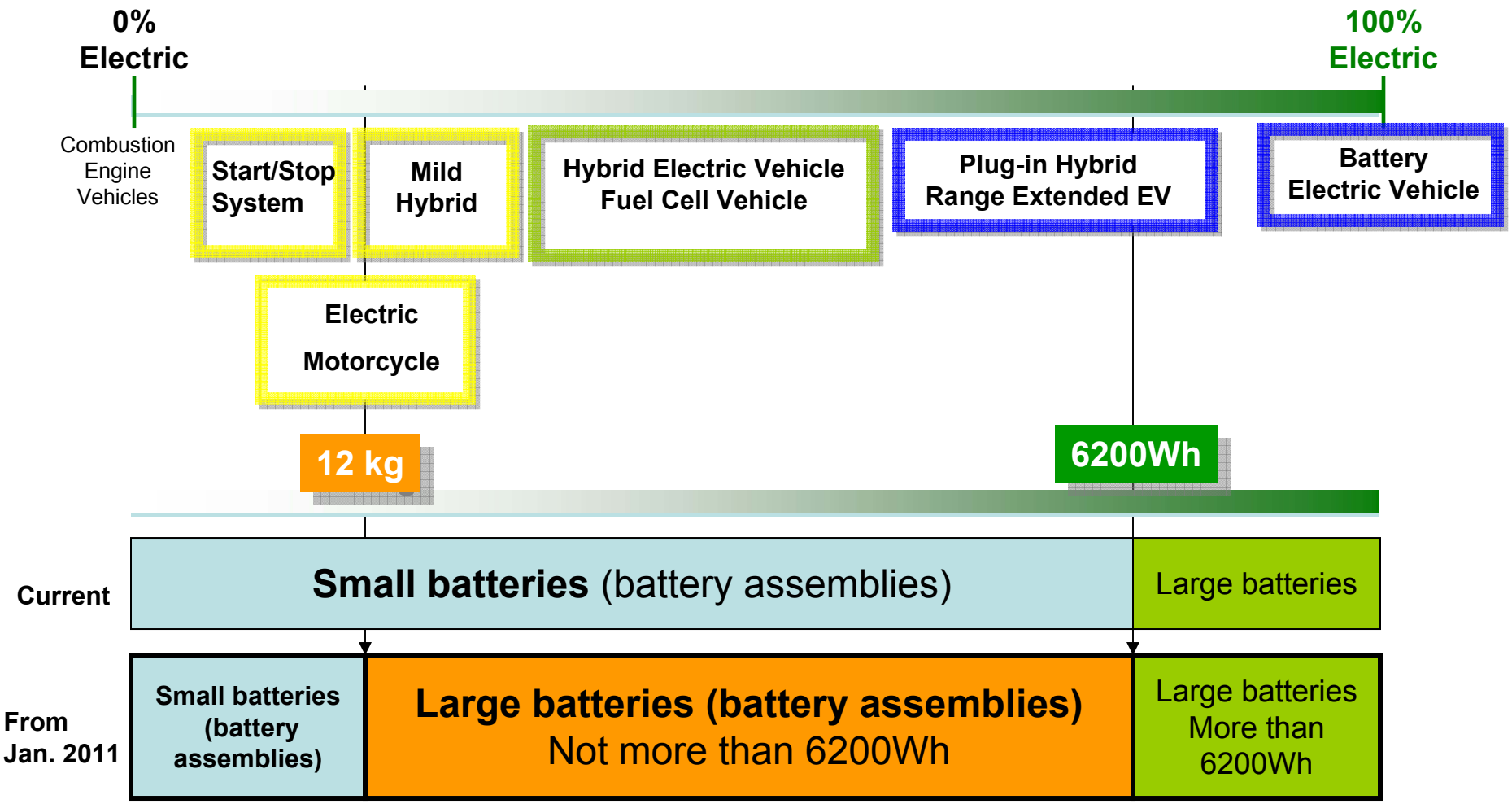
Vibration Test for Large Lithium-ion Battery Assemblies on UN Transportation Manual of Tests & Criteria

JARI

Battery Transportation Working Group

The Adopted Amendment of Classification on Large/Small Battery



Number of Batteries Required for Testing

Test #	Current	Adopted amendment to next revision	
	Small battery Not more than 6200Wh	**Large battery not more than 6200Wh and its mass more than 12 kg**	**Large battery More than 6200Wh**
T-1 altitude simulation	**16 batteries**	**4 batteries**	**4 batteries** **battery assembly that is consisted with batteries that have passed all applicable tests does not need to be tested if it is equipped with a system capable of monitoring the battery assembly and preventing short circuits, or over discharge between the batteries in the assembly and any overheat or overcharge of the battery assembly.**
T-2 thermal			
T-3 vibration			
T-4 shock (150 Gn for small batteries, 50 Gn for large batteries)			
T-5 external short circuit			
T-7 overcharge	**8 batteries**	**4 batteries**	
Required number of battery assemblies	**24 battery assemblies**	**At least 1 battery assembly,**	**4 battery assemblies, but not required when above satisfied, for example, EVs.**

Note: T-6(impact) and T-8(forced discharge) are required for cells.

T3. Vibration Test

38.3.4.3.1 **Purpose**

- **This test simulates vibration during transport.**

38.3.4.3.1 **Test procedure**

- **Cells and batteries are firmly secured to the platform of the vibration machine without distorting the cells in such a manner as to faithfully transmit the vibration.**
- The vibration shall be 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 mounting positions of the cell. One of the directions of vibration must be perpendicular to the terminal face.**

Background Information from the working group of the 4th revision of UN Tests and Criteria

ST/SG/AC.10/1998/30 submitted by the Expert of Canada

6. Some elements of the existing test series are not relevant to a non-operating cell or battery packaged for transport, however, some elements of the existing test series will be retained and strengthened in order to compensate for some of these deletions. Specifically:
   a) the extreme temperature exposure test is expanded to stress connections within cells and battery packs;
   b) **the vibration test is expanded in frequency range to be representative of conditions of all modes of transport;** and
   c) the current shock test is replaced by a more universal shock test.

Generic Description of Transportation Circumstance in the ICAO Technical Instruction

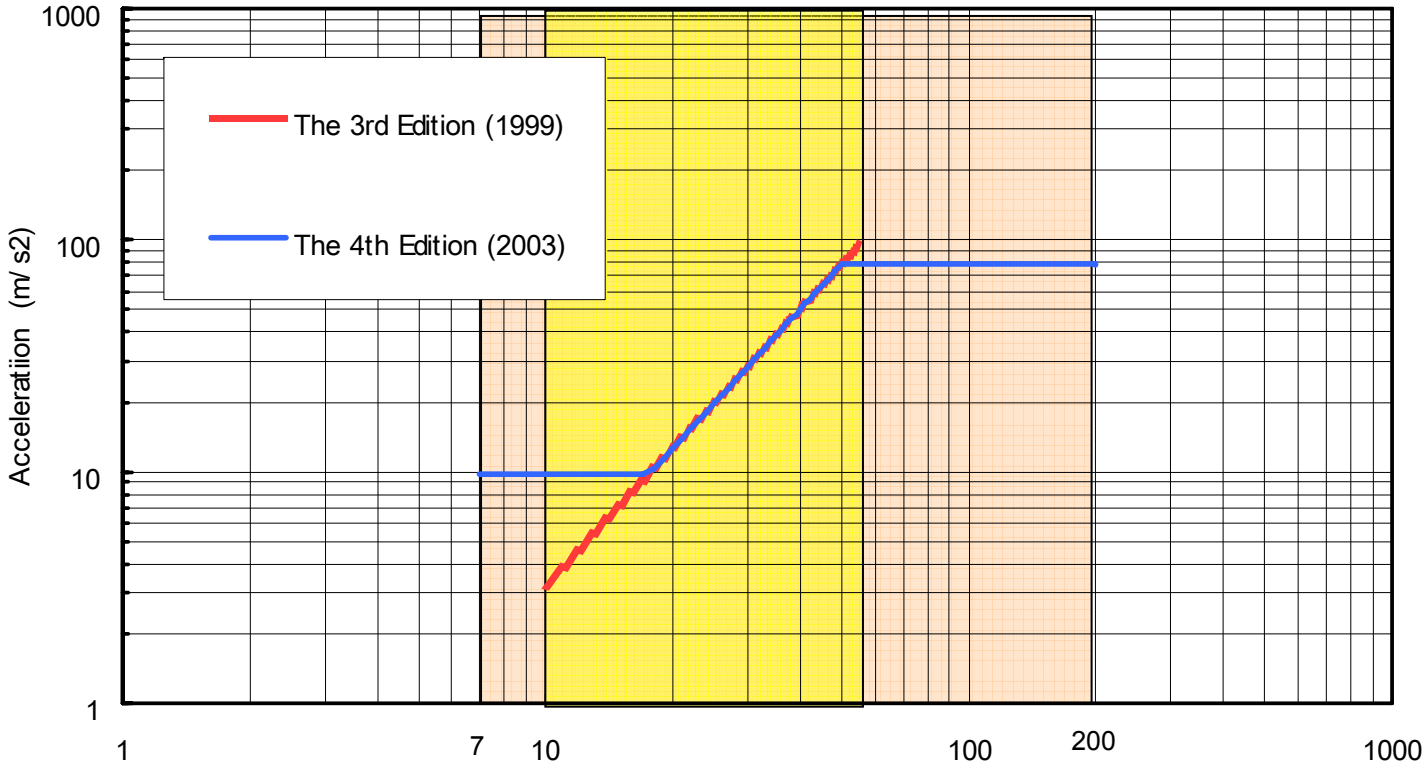
Vibrations: Vibrations in commercial aircraft from which packages may be exposed ranging from 5 mm amplitude at 7 Hz (corresponding to 1 g acceleration), to 0.05 mm amplitude at 200 Hz (corresponding to 8 g acceleration).

ICAO TI and IATA Dangerous Goods Regulations describe Generic Transportation Circumstance about Temperature, Pressure and Vibration.

The current vibration test conditions are referred to this description, the frequency range 7 Hz to 200 Hz and the vibration acceleration of 8 g at maximum.

Change of Vibration Test Condition since the 4th Revised Edition

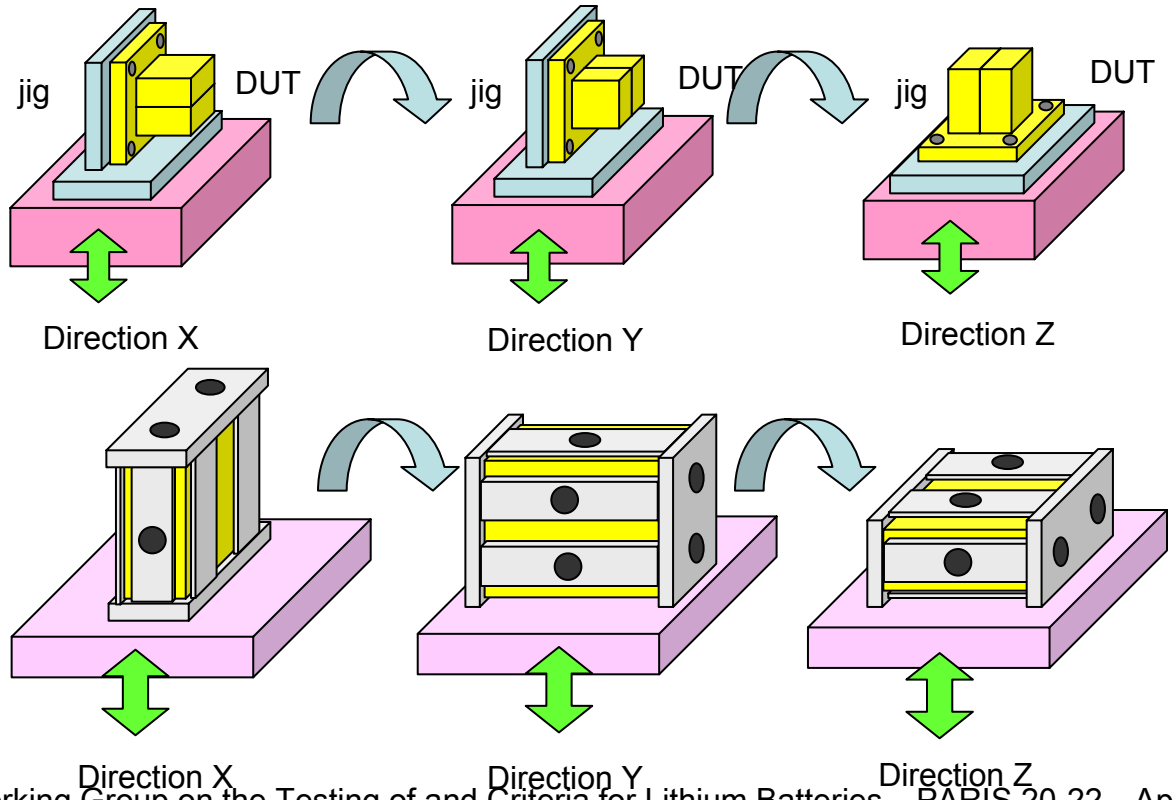
Since the 4th revised edition, the specified frequency range was expanded from 10 Hz - 55 Hz (the 3rd edition) to 7 Hz - 200 Hz, in order to account for the generic transport circumstance of aircraft.



Vibration Test Methods of Three Directions for Small DUTs

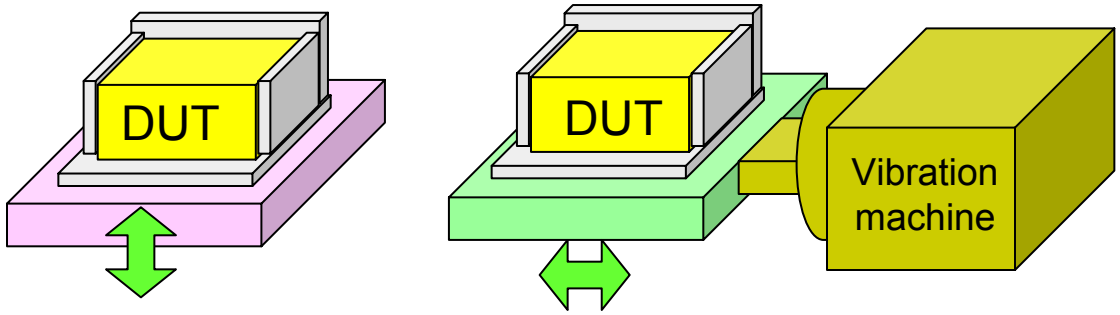
Fix the DUT with an attachment or jig to the platform and turn it to set in the proper direction when change the vibration direction.
The attachment or jig should be designed in order to avoid harmful influences from resonant vibration of jig and DUT in the test frequency range.

Note: DUT(Device Under Test)

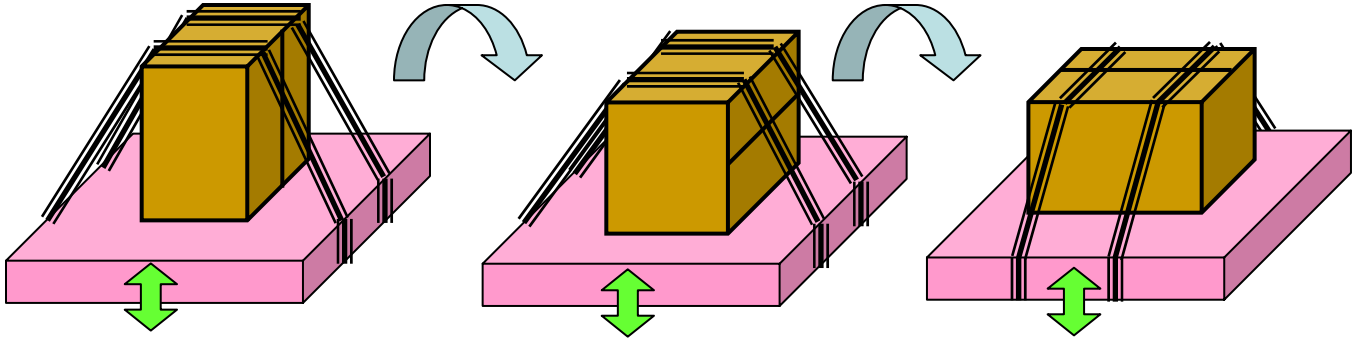


Typical Method of Securing and Test in Three Directions for Ordinary Size of DUTs

Use two kinds of vibration machines



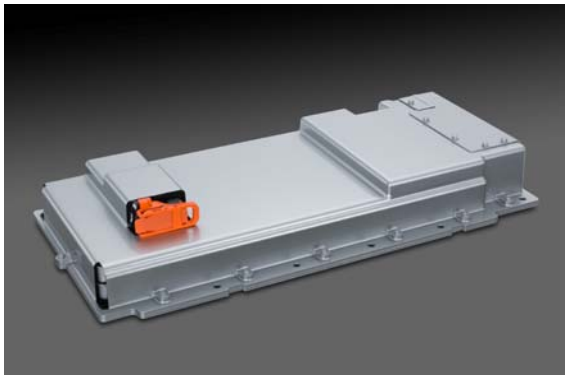
Or use a same vibration machines by turn the packaging.



Firmly secured by belts

Battery Pack Designs

Lithium Ion Battery Packs for Automobiles


Current Mass Production Battery Pack Designs

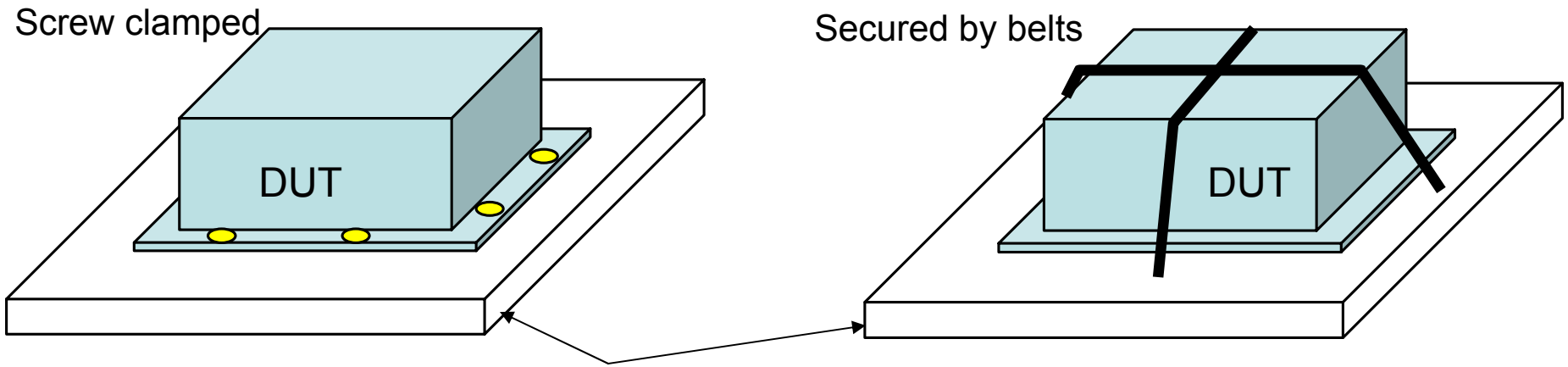


Test Requirements for Large Battery Packs

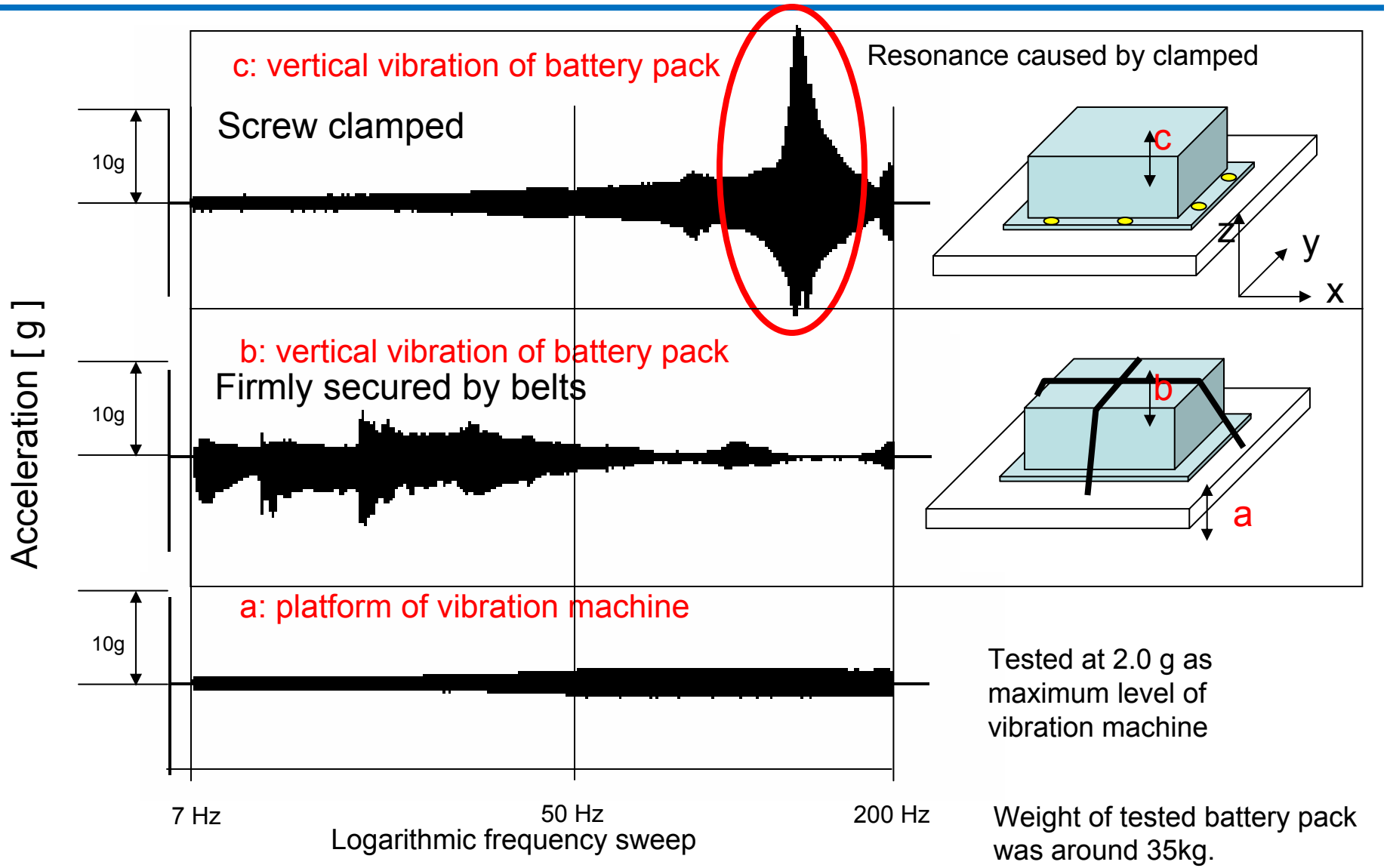
- Lithium ion battery packs are required to pass UN Tests and Criteria Section 38.3, same as lithium ion cells.
- Lithium Ion Battery Packs are electric storage systems which are made by assembling cells or modules with connection by bus-bars/electric wires and have at least one disconnect plug and are composed of other necessary electronic units.
- The battery packs have appropriate strength resistant in order to meet the automobile design requirements.
- Such battery packs are mainly no more than 6200 Wh in capacity. They will be categorized as “Large battery” after January of 2011. However, they are still required to pass UN Tests same as battery cells.
- The gross weight is generally proportional to its battery capacity, also dependent of its system design, and from 12 kg to 100 kg or more.

Vibration Test Methods for Large Format Battery Packs

- Large, heavyweight and sophisticated battery pack (DUT) has much difficulty in conducting mechanical vibration (T.3) and shock (T.4) tests and also needs testing facilities of enough capability.
- Current test procedure states that “Cells and batteries are **firmly secured to the platform** of the vibration machine without distorting the cells in such a manner as to **faithfully transmit the vibration**.”
- To secure such a large and heavy DUT to the platform during vibration tests in 3D orthogonal axes, the DUT has to be clamped by screw, instead of by belts in a normal transport style.



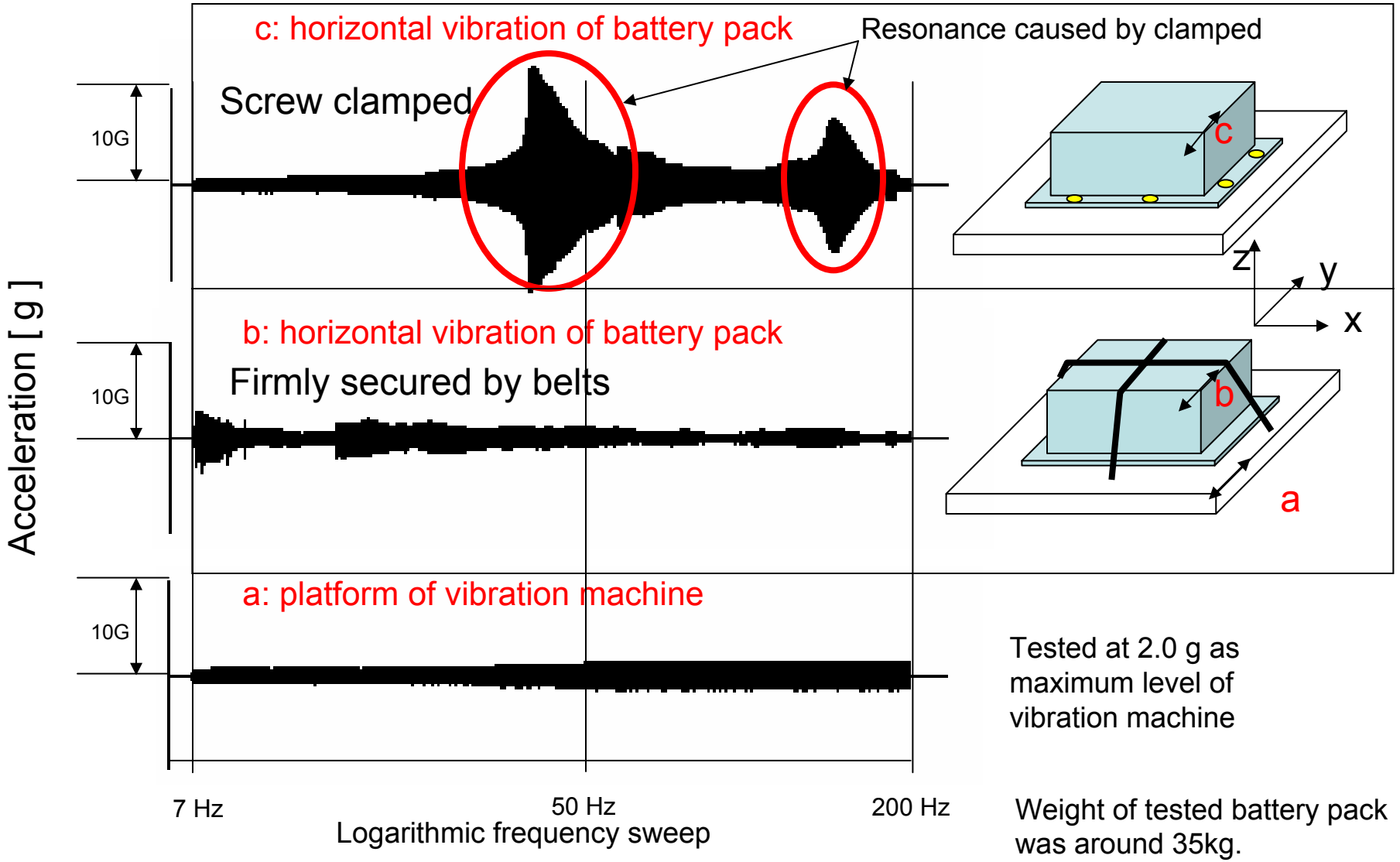
Difference of Vibration Transmission (z-axis)



Tested at 2.0 g as maximum level of vibration machine

Weight of tested battery pack was around 35kg.

Difference of Vibration Transmission (y-axis)



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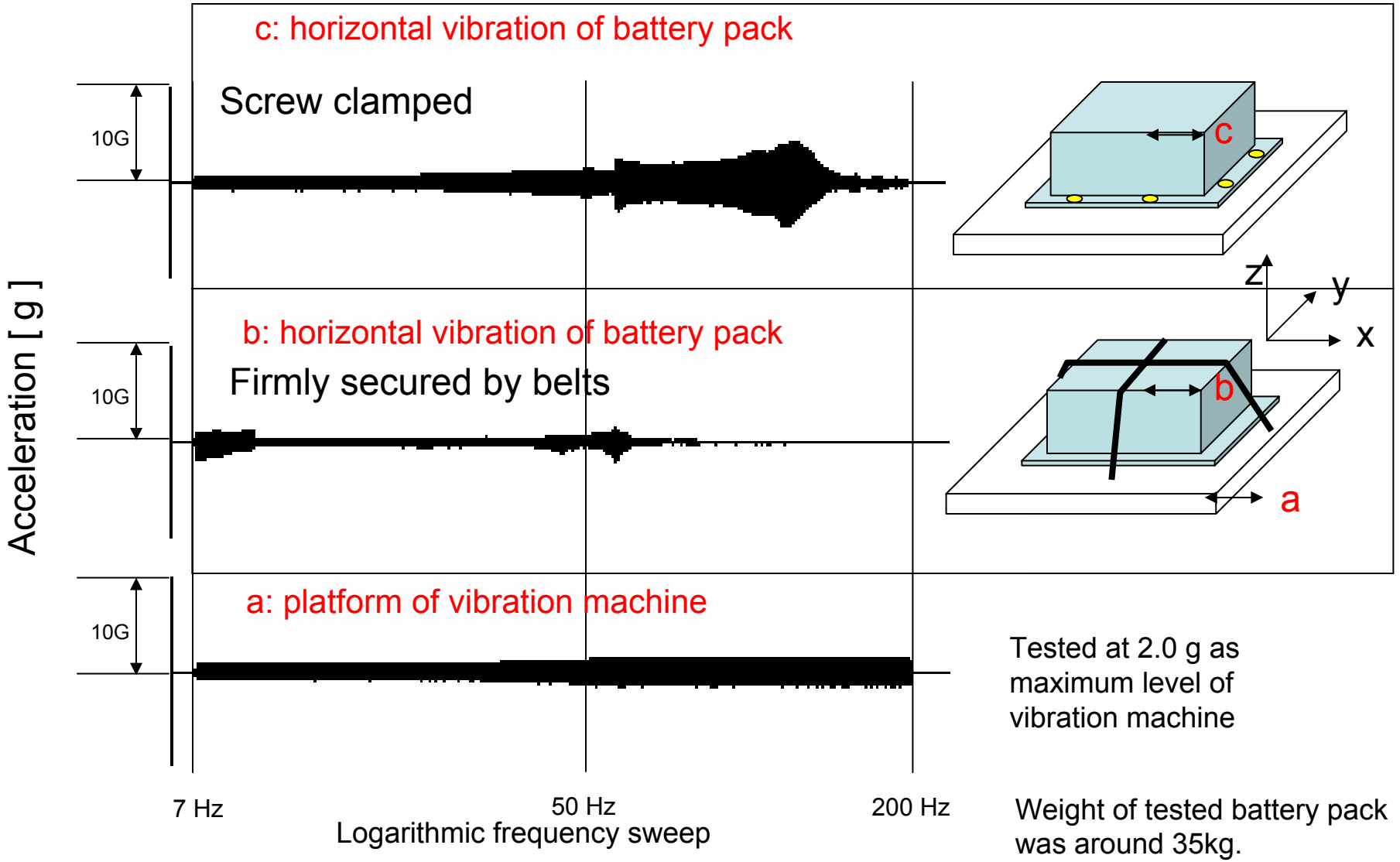
Difference of Vibration Transmission (x-axis)



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Observation

- From the result of all three tests, it is obvious that vibration level of DUT is much lower at more than 50 Hz when DUTs are secured by belts. When comparing clamping and belt-securing method, there is a big difference in both vibration transmission level and unexpected resonant behaviors.
- Horizontal vibration is much lower than vertical vibration in the meaning of transmissibility when DUT is secured by belts. It is rathional that the friction between DUT and platform (floor plane) reduces the transmission of vibration.
- Current test procedure, which requires clamping, induces an excessive requirement of resistant strength for large & heavy battery pack for automotive use beyond what's required in real transportation style, in order to pass the criteria.

Necessity to Revise T.3 Requirement & Procedure for Large Batteries

- There are several standards related to Vibration Tests such as;
  - ISO/CD 12405 “Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems — Part 1: High power applications” is now in work by ISO TC22/SC21 LIBPT.
  - ISO 16750-3 (2007) “Road vehicles -- Environmental conditions and testing for electrical and electronic equipment -- Part 3: Mechanical loads” defines test procedures and conditions for automobile parts evaluation.
  - RTCALDO- 160D (1997) “ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT” is used in the robust vibration test for different aircraft types with best selected test profile.
- We believe that test requirement should be revised from battery pack design.