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Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals

Sub-Committee of Experts on the Transport of Dangerous Goods

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Item 5 of the provisional agenda
Electric storage systems

Testing of large lithium batteries and lithium battery assemblies

Transmitted by the Council on the Safe Transportation of Hazardous Articles (COSTHA)[1]

Introduction

1. Among COSTHA's membership is a group identified as the North American Automotive HAZMAT Action Committee (NAAHAC). Participants in this committee include twelve automobile manufacturers from around the world who operate in the United States. Additionally, COSTHA counts five members who are direct suppliers to the automotive industry, providing numerous materials and devices for production support.

2. The Sub-Committee has recognized the need to review the UN Manual of Tests and Criteria, specifically Section 38.3 as they relate to the transport of large lithium batteries and assemblies. COSTHA supports the efforts of the Sub-Committee in this endeavour and would like to present data to further the discussion.

Discussion

3. The concern over the testing of large format lithium ion batteries was discussed at length during the Informal Working Group on Batteries held 11 November to 13 November 2008. At this meeting, Delphi, a COSTHA member organization, provided a

[1] In accordance with the programme of work of the Sub-Committee for 2009-2010 approved by the Committee at its fourth session (refer to ST/SG/AC.10/C.3/68, para. 118 (c) and ST/SG/AC.10/36, para. 14).

presentation detailing the concerns facing the gasoline-electric hybrid vehicle, hydrogen fuel cell hybrid-electric vehicle, and pure battery electric vehicle manufacturers and suppliers with regards to the testing of these "large" batteries. Specifically, the UN Tests T3 and T4 were identified as posing significant design issues for the battery manufacturers.

4. While the concerns over the T3 test have been addressed by previous COSTHA presentations, the issue of T4 has not been fully addressed by the informal working group as the technology develops in real time. The large format battery issue is not focused on only automotive batteries, although that industry may be the most visible. Large format batteries are found in commercial aviation, military applications, as well as continuous power supply systems.

5. Large format batteries are defined as those batteries having a gross mass greater than 12 kg. Assemblies of batteries having a aggregate lithium content greater than 500 g for lithium metal or a Watt-hour rating of more than 6,200 Watt-hours is not required to be tested as long as the assembly 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. Therefore the application of the T4 in question is below 6,200 Watt-hours for lithium ion battery assemblies.

6. Test 4 currently requires cells and batteries to be subjected to a half-sine shock of peak acceleration of 150 g_n and a pulse duration of 6 milliseconds. The shock test includes 3 shocks in the positive and 3 shocks in the negative direction in 3 mutually perpendicular mounting positions of the cell or battery. For large format batteries (gross mass greater than 12 kg), the peak acceleration shall be 50 g_n and a pulse duration of 11 milliseconds.

7. Such a testing regime is logical for batteries with a gross mass less than 12 kg. However, when gross mass increases above 12 kg, the physics of the test become very difficult to replicate. The current conditions of the test vary the peak acceleration based on the battery gross mass. Given the purpose of the T4 test as stated in 38.3.4.4.1 is to "simulate possible impacts during transport", the forces generated from the application of specified acceleration in T4 greatly exceeds those encountered in severe transport conditions. Thus, the required peak acceleration of 50 g_n is unreasonable abuse given a review of available testing data.

Review of current testing requirements

8. Batteries and battery assemblies are manufactured in various ways to address use conditions. For example, battery assemblies that will be non-mobile and will only be transported for set up may have minimal protective casing. Hybrid or electric vehicles designed to withstand crash testing will have energy absorbing casings. Thus, it is difficult to focus solely on the forces applied to the cells or component batteries when determining if test forces are being applied. A more generalized approach was suggested by the lithium battery informal working group.

9. A review of available testing standards and requirements similar to the T4 was conducted. These references include:

- SAE J2464 Shock Test used for testing of components installed on a vehicle (simulating a crash)
- RTCA DO-160F Shock Test used to test equipment installed on airborne equipment.
- USAF ASD-TR-76-30 December 1977 – Report including recommendations of aircraft restraint systems based on military crash data and forces encountered.

- FAA 14CFR 25.561 – United States Federal Aviation Regulations applicable to installed equipment onboard aircraft.
- ISO/DIS 12405-1 - Electrically propelled road vehicles — Test specification for Lithium- Ion traction battery packs and systems — Part 1: High power applications

These documents will be submitted as informal documents to support the discussion.

10. Provided below is a table comparing each of the standards and the acceleration required in each test.

Spec	*UN 38.3, T4*	*SAE J2464*	*RTCA DO-160F Airborne Equipment*	*USAF ASD-TR-76-30 December 1977 FAA 14CFR 25.561*	*ISO/DIS 12405-1*
Acceleration (g_n)	50	25	20	9 20 g_n is non-survivable limit cargo aircraft	50
Pulse Form	Half sine	Half sine	Saw tooth	Crash data	Half sine
Duration (ms)	11	15	11		10
Total # shocks	18 3 repeats 3 axes +/- directions Mass >12 kg	18 3 repeats 3 axes +/- directions Mass limit unspecified	6 3 orthogonal axes +/- directions Mass limit unspecified	Load restraint	6 3 orthogonal axes +/- directions

11. The current UN 38.3 T4 test was derived from using the IEC 68-2-27 standard activity since there was a general lack of research data on the subject at the time. A quick review of other applicable standards (SAE J2464, RTCA DO-160F, and USAF ASD-TR-76-30) indicates significant differences in standards for transport vehicles themselves.

12. The USAF Technical Report ASD-TR-76-30 provides an important observation based on real world crash test data. Below is an excerpt from the document:

*The most interesting factor found was the relationship between different Gs. At first glance that statement does not make sense. How can there be different Gs? It is a question that has been with us for 35 years. One should not talk in terms of Gs, but of force. During FAA crash tests, it was found that instrumentation on pallet loads and seats recorded different Gs at the same lateral location in the aircraft. This can be explained as follows: A seat is hard mounted to the aircraft floor while the pallet is free to move on rollers within the rail system. This freedom allows the absorption of energy as the pallet presses against the rail locks. Further, the shifting of cargo and give in the netting system acts in the same way. The result was that the cargo reacted to approximately one half the G force of the seat. Another fact is that the crushing of the aircraft itself has the same effect, where the tail would see a very low G force compared to the nose. An aircraft with **20G** pilot seats, 16G passenger seats, and **9G cargo restraint**, is in reality compatible…*

*Throughout the history of doing this study many people could not relate to a G load. The following is to provide a basic guide of loads incurred during various phases. In general, under a normal landing the G forces tend to be between **0.1** and O.2G; under an assault landing condition it is a little higher. The maximum landing loads that the C-130, C-141, and **C-5** can generate are 0.94, 1.05, and 1.20G,* *respectively. This is assuming full reverse thrust, full braking, and a loose dirt runway.* ***For any load above these, the aircraft is in a crash condition as defined by this report.***

13. The USAF Study is based on a review of crash incident data collected from cargo type aircraft accidents from 1962 to July 1976. This study is still used as a reference for military and civilian restraint requirements and standards, including the RTCA DO-160F. The study recommends the standards of 20 g_n be used for equipment installed on aircraft (such as pilot seats) which will be nearest to the front of the aircraft (and likely would absorb the greatest about of force), 16 g_n for passenger seats (further from the bulk of the force), and 9 g_n for cargo restraint systems (since they will be further from the force, and will additionally deform to reduce force). A review of the normal landing forces (when normal transport forces will be maximized in aviation) for a military cargo aircraft is 1.20 g_n. Therefore, the 9 g_n standard used for cargo restraint systems is 7.5 times the acceleration observed in normal transport conditions. It is also important to note that the report concludes that a condition involving a 20 g_n acceleration is a non-survivable event.

14. COSTHA acknowledges that although this data is over thirty years old the basic premise remains constant, and this report is in fact used as the basis for other aviation standards. It is clear from this comparison that safety factors might benefit from additional research based on evolving actual transport conditions. Industry today is progressing forward with new technologies which are pushing the limits of the regulatory texts currently published.

Proposal

15. Based on the available data from the above cited sources, COSTHA proposes the acceleration in the T4 test for large format batteries (>12 kg gross mass) be reduced from 50 g_n to 9 g_n (and adjusting the duration accordingly). This value is in alignment with currently accepted standards for aircraft cargo restraint systems (where cargo would be stored), and is as much as 7.5 times higher than the maximum accelerations observed during normal transport conditions.

16. The revised 38.3.4.4.2 Test Procedure, second paragraph would read:

> However, large cells and large batteries shall be subjected to a half-sine of peak acceleration of ~~50~~ 9 g_n and pulse duration of [11] milliseconds. Each cell or battery is subjected to three shocks in the positive direction followed by three shocks in the negative direction of each of three mutually perpendicular mounting positions of the cell for a total of 18 shocks.

17. Given that much of this research is over thirty years old, COSTHA requests the Sub-Committee recommend additional studies be conducted on the actual conditions of transport given the advancements made with modern day aircraft technology. Such studies could be conducted by Competent Authorities, Industry, or joint cooperatives. The findings of these studies would be reviewed by the Sub-Committee for consideration of future changes to the transport requirements.