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Safety Issues, Considerations, Evaluation and Extrication of Electrical Vehicles Involving Fire Incidents.

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ABSTRACT : *In today s fast paced era as we see the innovations are taking place in a larger amount, at past passenger vehicles had been introduced by using petrol and diesel as a fuel intakes, but today in addition to a Hybrid vehicle even Electrical vehicles had been existed which reduces the effort of travelling and expenditure on fuels but rescue personnel in being exposed to hazardous chemicals such as corrosive chemicals, toxic fumes, fire and electric shock in the event of a crash. Because of these high risk factors manufacturers are understood to develop appropriate procedure for dealing with these crashes.Several evaluation programme s had been carried out by different countries like Australia, Japan for a purpose of evaluating the involvement of crashes. New car Assessment programs have subjected several petrol-electric hybrid vehicles to the 64km/hr frontal offset crash, 50km/hr barrier side impact test and the 29km/hr side pole test. None problems with the electrical systems and batteries were encountered., these tests even involved vehicles with lead acid or NiMH batteries. Lithium – ion batteries which are becoming popular for movement in electrical vehicles and these might introduce different hazards for crash test and rescue personnel.A crash test of an electrical car with a lithium – ion battery was carried out by Australian NCAP and Japan NCAP in a month of October 2010. And euro NCAP has also evaluated a number of vehicles with Li-ion battery . This paper reviews those potential hazards and provides advice for minimizing risks and provides the advices for the crash test.*

I. INTRODUCTION

Several crash tests were performed by different countries named with different programmes. The Australian car Assessment Program, US InsuranceInstitute of high way safety, Euro NCAP, Japan NCAP, and Korean NCAP have conducted frontal offset crash tests since the mid 1900s. They also conducted 29km/hr side pole tests. The tests were carried out by using conventional fuels petrol and diesel. There had been several cases where there has been a fuel leaked due to disturbances in the fuel lines or rupture of fuel tank and after conducting several experiments the Australian Car Assessment program has experienced one minor fire where electrical short ignited some foam plastic insulation near the crushed radiator.This paper reviews with the potential hazards and provides advice for minimizing risks. Today both electric and electric hybrid vehicles potentially introduce new types of post crash products. It is stressed, however, that experience with electrical vehicles is limited and that this advice will need to be reviewed as more information becomes available. It is also acknowledged that the vehicle manufacturers have put considerable resources into developing safe and reliable electrical systems for the current generation of electrical vehicles. A serious incident involving a lithium-ion car battery is considered to be highly unlikely but it is important that crash test organizations understand and are prepared for potential hazards.

II. ELECTRICALLY PROPELLED AUTOMOBILE TECHNOLOGY

Mr. Edison who took an initiative in developing a storage battery to make it useful in propelling vehicles and road vehicles. He saw that there are two viewpoints that of the electrical man with his instruments, his rules of efficient operation and reasonable life of battery, his absolute knowledge that the same care should be given a vehicle battery that is given a valued horse or even a rail road locomotive; and this of the automobile driver, who simply wishes to go somewhere with his car, and who, when he arrives somewhere, wishes to go back. And in the long promised storage battery the highly practical nature of Edison’s work is once more exemplified in that he has held uncompromisingly to the automobiles point of view.However the popularity of electric vehicles soon declined when electric batteries could not match the price and energy density of petroleum fuelled vehicles.

Keeping the reduction of fuel consumption in mind an electrical hybrid vehicles were developed in response to the environmental concerns. Most hybrid models have hard nickel metal Hybrid storage. These were tested by NCAP and no problems were associated with electrical systems were encountered. Some operations were developed in consultations with vehicles manufacturers. Recently Li-ion Lithium-ion batteries have been increasingly used for electrical storages in all electrical vehicles but they used negative reputation as the tires associated with aircraft travel were encountered in late 1990s.It was observed that the fires in the laptops are oriented due to ignition of a single cell as laptop is composed of several cells, so ignition of one cell takes place to burning of entire Laptop. At that case the recommended command is to extinguish the flames with a Halon 1211 extinguisher then douse the computer with water . Smothering with ice or some other covering should be avoided as this causes heat to build up and ignite adjacent cells.

Figure 1 – frame from an FAA video

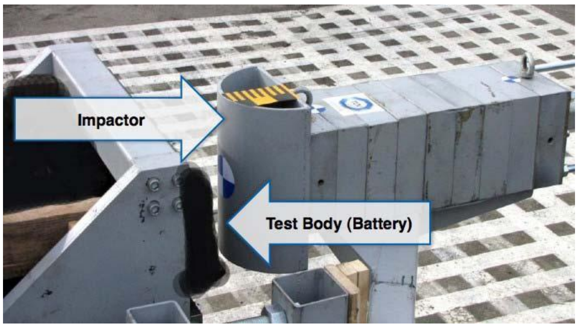
"Extinguishing in-flight laptop computer files"Dosing with copious amount of water does appear to be successful in these cases but it does contravene the normal advice that water should not be used on lithium fires since lithium can ignite when contacts water.

Lithium-Ion vehicle Batteries : Li-ion batteries are much more sophisticated than laptop computer batteries. There are numerous levels of automatically isolating stored electrical energy and they have inbuilt cooling systems to prevent heat build-up under most foreseeable circumstances.Serve testing of Li-ion batteries has been conducted:

Sandia National Laboratories' Battery Abuse Testing Laboratory, which has become the de facto automotive battery-testing shop in the U.S. The lab heats, shocks, punctures and crushes batteries to see how safe they would be in crashes and extreme operating conditions.When lithium-ion cells first came to the laptop market, "the active materials were very energetic. There were some significant field failures," notes Chris Orendorff, the battery lab's team leader. The usual cause was thermal runaway, a chemical reaction that could start from excessive overheating, and then potentially cause a cell to catch fire or explode. Although even extreme driving conditions are unlikely to trigger those problems, a crash could, and so could a sudden overcharge - for example, if lightning struck a charging port while a car was being recharged.Small tweaks in chemistry can make a large difference in how well battery packs resist overheating or exploding. "Half a dozen different chemistries are still being considered as viable" in terms of performance and safety, Orendorff says. Sandia is seeing more designs with lithium iron phosphate cathodes, for example, because they stay cool and suffer little degradation over time. Additionally, batteries with anodes made from lithium titanate seem less likely to overheat even under hot driving conditions. Electrolytes containing different lithium salts are still being tested for greatest stability, too. Manufacturers are also testing a variety of mechanical safety features similar to measures developed to prevent thermal runaway in laptop lithium batteries. (Direct quote from Fischetti 2010)

Orendroff further advises that sandia has studied Li-Ion batteries under various mechanical abuse conditions, including full battery crush. The biggest concern with these systems is the uncertainty about the battery state of health after mechanical abuse. Sometimes connectors can be broken and communication is lost to a part of all of the battery with an unknown amount of energy remaining in the system. Handling and disposal become a significant concern.Issues related to the battery failure upon abuse would be evidence of venting, leaking electrolyte (carbonate water are highly flammable), thermal hazards (Sandia observed battery temperature in excess of 1200 C for high order thermal runway upon failure) and particular hazards.TÜV SÜD Automotive in Germany has also conducted impact testing of Li-ion car batteries. Figure 2 shows a test rig with a cylindrical impactor. Dr L Wech (personal correspondence) advises that the organization carries out tests that simulate severe deformation of the battery pack in a crash. They use

Figure 2. Li-ion battery test to be conducted by TÜV SÜD



Different geometrical forms of the impactor, different masses of the impactor and different impact velocities tests are performed in the open air. Staff are equipped with protective clothing and trained fire-fighting personnel are available. The temperature inside the battery is monitored during the tests and for a long time the test.

CRASHES THAT MIGHT CHALLENGE BATTERY INTEGRITY : ANCAP and Euro NCAP have conducted 64km/h offset crash tests of the Mitsubishi i-MiEV electric car. No problems with the battery or high-voltage electrical system were encountered in either crash test and the automatic safety systems operated as designed. In the ANCAP tests (conducted at JARI in Japan) the peak vehicle body deceleration was 38g, measured at the base of the driver-side B-pillar. This deceleration is typical for a small car in this type of crash test (Paine 2009).

Euro NCAP also conducted a 29km/h pole test of the i-MiEV. Again no problems with the battery or high-voltage electrical system were encountered. However, Figure 7 illustrates that the vehicle body deformation came close to the exterior of the battery pack, which is mounted under the rear floor.

Figure 3. 64km/h offset crash test conducted by JARI for ANCAP

Figure 4. Post crash electrical tests

Figure 5. Visual indicator of active high voltage used by JARI during the ANCAP

The 29km/h pole impact test places severe demands on the vehicle structure. The majority of casualty crashes involving side impacts with narrow objects occur at impact speeds no more than this (Otte 2009**)**. However, higher speed impacts do occur in real-world crashes and it is appropriate to consider the possible consequences of such a crash.

Figure 6. Overhead view at peak of 29km/h pole impact test on i-MiEV

Figure 7. Post crash underside view of vehicle deformation. Battery pack is under the plastic panel at left

ANCAP recently conducted a research crash test where a medium size (non-electric) sedan was subjected to a side pole crash test with the impact speed increased to 50km/h. A side pole test at 29k/h had already been conducted and so the vehicles could be compared. Figures 8-11 show the comparisons.It is evident that there is substantially more intrusion in the 50km/h impact, including the rear floor area, compared with the 29km/h impact. Of course, no battery was present in this test and so no conclusion can be drawn about the likelihood of battery damage. However the test does suggest that further research should be conducted into this mode of crash with electric vehicles.A50km/h side pole impact is a very severe crash and there is a high likelihood of occupant fatality (based on Otte 2009). The main concern with electric vehicles is the potential danger to rescuers and other road users.

Figure 8. ANCAP research crash test at 50km/h

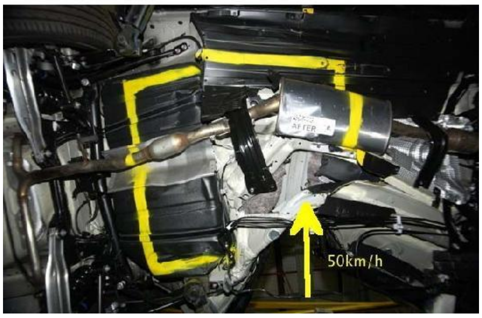


Figure 9. Underside of 50km/h vehicle. The yellow rectangle shows the approximate location of the rear floor area.

Figure 10. Same model in 29km/h impact

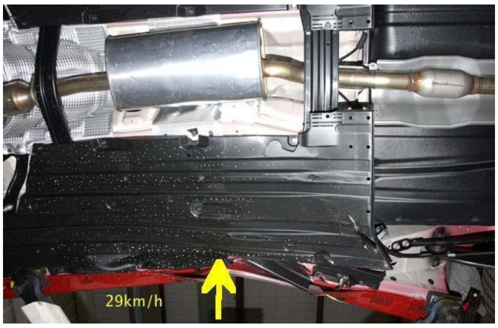


Figure 11. Underside of 29km/h vehicle. Rear is to right

In a multi-vehicle crash the other issue to consider is the risk of the other vehicle catching fire and the fire spreading to the electric vehicle. Digges (2009) reports that in 1% of vehicle fatalities in the USA fire is recorded as the most harmful event. Fires are recorded in 0.2% of NASS cases (weighted). A provisional assessment is therefore that the probability of an electric vehicle with an Li-ion battery colliding with a conventional vehicle that catches fire is extremely low.

POST-CRASH PROCEDURES : The Appendix sets out possible procedures for dealing with crashes involving vehicles with Li-ion batteries. This is based on a review of available documentation from manufacturers and emergency rescue organizations. It was found that information was somewhat sketchy and was sometimes contradictory. Some examples are given below.Vehicle manufacturer A: "In case of vehicle fire, inform fire department immediately and start extinguishing the fire if possible.

[1] By fire extinguisher. Use the type of fire extinguisher which is suitable for flammable liquid or electrical equipment fires.

[2] By water. NEVER EXTINGUSH BY SMALL VOLUME OF WATER. It is quite dangerous. This is only possible if you can use a large volume of water (e.g. from fire-hydrant), otherwise wait for fire department to arrive on the scene."

Vehicle manufacturer B: "In case of vehicle fire, contact the fire department immediately and extinguish the fire if possible... In case of extinguishing fire with water, large amounts of water from a fire hydrant (if possible) must be used. DO NOT extinguish fire with a small amount of water. Small amounts of water will make toxic gas produced by a chemical between the Li-ion battery electrolyte and water. In the event of small fire, a Type BC fire extinguisher may be used for an electrical fire caused by wiring harness, electrical components, etc. or oil fire"A manual for vehicle rescuers: "*Do not use water* or foam to extinguish lithium-ion battery fires. Extinguish lithium-ion battery fires with dry sand, sodium chloride powder, graphite powder, or copper powder.

Copious amounts of water and/or foam can be used on electric vehicle fires with no danger to response personnel of electrical shock. Cleanup lithium-ion electrolyte spills with dry sand or other noncombustible material and place into container for disposal."

III. CONCLUSIONS

Further research should be conducted into the robustness of Li-ion batteries in a crash situation. In particular, investigation should consider the types and severities of crash that can be expected to place severe demands on in the in-built safety systems of electric vehicles and their batteries.Further research is also needed to develop appropriate and consistent post-crash procedures for dealing with electric vehicles, including fires. A draft for such procedures is provided in the Appendix.In the case of crash test organisations, there are several extra pre-crash arrangements that should be put into place in preparation for an electric vehicle crash test (also set out in the Appendix). Based on this initial research, consideration should be given to having available special fire-fighting equipment, as well as thermal imaging equipment, to remotely check for hot-spots around key vehicle components, and a gas monitor to check for flammable or toxic gases) near the crashed vehicle.

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APPENDIX - DRAFT PROCEDURES FOR CRASHES INVOLVING ELECTRIC VEHICLE WITH LITHIUM-ION BATTERIES

Caution: There are inconsistencies in the referenced advice for dealing with fires that involve lithium-ion batteries. Further research is necessary to resolve these inconsistencies. The following procedures are provided as a basis for development of an international procedure for this purpose and are not intended to be applied in real-world situations in their current form.

PRE-CRASH PREPARATIONS

[1] Train staff in use of a (recommended) thermal imaging equipment to locate hot spots in the vehicle after the crash

[2] Train staff in use of a (recommended) gas monitor unit for detecting flammable and toxic gases

[3] Conduct a trial run of manufacturer's rescue manual, including operation of the (manual) battery isolation switch, backup procedures (if any) if the isolation switch is not operable (e.g. due to crash damage), identification of high voltage components, identification of battery fluid leaks and external battery damage and, if available, procedures to safely discharge the battery (which should be fully charged for the crash test)

[4] Measure the electrical resistance at key points, in accordance with ECE/TRANS/WP .29/2010/122 (the same points are also measured after the test, when the vehicle has been declared safe for post-crash assessment). Also fit an external indicator in a prominent exterior location (such as the C-pillar) to show when the high voltage circuit is active.

[5] Assess evacuation routes for all personnel who will attend the crash test. From every observation area there must be an evacuation route that does not involve approaching the crash test area. Also determine evacuation assembly points and head-count procedures.

[6] Train appropriate staff in fire fighting procedures and ensure there is suitable fire-fighting equipment, including high volume water hoses that will reach the crash test area and protective clothing/equipment.

[7] Develop and implement a plan for containment of leaked hazardous fluid

[8] Notify local emergency services of the proposed crash test date and time and provide them with necessary information, including the circumstances under which they might be summoned (see flow chart). Where possible, emergency service personnel should attend the crash test (this can be useful experience for these personnel).

[9] Notify the vehicle manufacturer and determine a contact person with appropriate technical knowledge who will be available (preferably in person) at the time of the crash test

[10] Prior to the crash test inform all observers about the potential hazards (fire, smoke, toxic gases, hazardous liquids), the signal for evacuation, the evacuation routes and the assembly points

POST-CRASH PROCEDURES

The draft flow diagram overleaf indicates the step to be taken to ensure that it is safe to conduct a post-crash inspection of the vehicle.

Crash