U.S. CONSUMER PRODUCT SAFETY COMMISSION
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June 13, 2016

Ms. Megan Sepper
UL 2272 Project Manager
Underwriters Laboratories Inc.
12 Laboratory Drive
Research Triangle Park, North Carolina 27709

Re: Proposed First Edition of the Standard for Electrical Systems for Self-Balancing Scooters dated April 15, 2016 (Comments due: June 14, 2016)

Dear Ms. Sepper:

U.S. Consumer Product Safety Commission (“CPSC”) staff appreciates this opportunity to provide comments on the proposed standard for Electrical Systems for Self-Balancing Scooters.[1] CPSC staff strongly supports this effort to address hazards associated with the electrical system of the self-balancing scooters in addition to the physical hazards associated with the use of self-balancing scooters that may also be related to the electrical system.

CPSC staff is investigating more than 60 self-balancing scooter fires in over 20 states, which resulted in more than $2 million in property damage. The fires have resulted in major destruction of two homes and an automobile. Additionally, CPSC staff estimates that 7,200 injuries associated with self-balancing scooters were seen in emergency departments between August 2015 and December 2015. Of these, 46 percent of the injuries were fractures and 19 percent were sprains and strains. Over half (56 percent) of the victims were adults and a majority of the victims were women (55 percent). Half (50 percent) of the injuries occurred in home locations while 43 percent of the incident locations were unknown. The estimates show that 97 percent of victims were treated and released.

CPSC staff proposed requirements and comments are provided below as items 1-11. New proposals are marked “(New).” Added text is shown underlined and deleted text is shown with a ~~line through it~~.

Item 1:

Based on CPSC staff investigation of scooter fire incidents, CPSC staff proposes to add requirements from UL 2580, *Batteries for Use in Electrical Vehicles,* Section 43 Internal Fire Exposure Test, to the proposed requirements for UL 2272 as follows:

(New) XX Internal Fire Exposure Test

[1] The comments or views expressed in this letter are those of the CPSC staff and they have not been reviewed or approved by, and may not reflect the views of, the Commission.

XX.1 The electric energy storage system shall be designed to prevent a single cell failure within the system from cascading into a fire and explosion of the DUT. This test is applicable to lithium ion technologies.
XX.2 The fully charged electric energy storage system (MOSOC- Maximum Operational State of Charge) is to be subjected to the internal fire test, which consists of heating one internal cell that is centrally located within the DUT until thermal runaway or otherwise forcing the thermal failure of a cell through any means necessary and determining whether or not that failure remains safely controlled within the DUT. Once the thermal runaway is initiated, the mechanism used to create thermal runaway is shut off or stopped and the DUT is subjected to a 1-h observation period.

Exception No. 1: Testing on a cell that is other than centrally located within the DUT may additionally be conducted if it is not clear which is the worst case scenario. The location of the failed cell is to be documented for each test.
Exception No. 2: Testing may be conducted on a representative subassembly consisting of one or more modules and surrounding representative environment, if it can be demonstrated that there is no propagation beyond the subassembly.

XX.3 As a result of the testing of XX.2, there shall be no fire propagating from the DUT or explosion of the DUT. See Table 21.1 for additional details. If a thermal runaway condition cannot be initiated, as demonstrated through testing, the DUT is considered to comply with the requirements of this test.

Rationale: It is well known that lithium-ion battery packs need critical safety circuits to maintain each of the cells within a safe operating range. It is crucial for battery safety to maintain the cell voltage, current, and temperature during charging, discharging, and storage within their specified ranges. If the cell is not maintained within its safe specifications, then the cell may overheat, leading to thermal runaway and vent with flames. Additonally, it is widely known in the industry that poor cell manufacturing can lead to internal cell shorts that cause cell thermal runaway. According to Weicker[2], “Inclusions of foreign matter, defects in the cell separator, and other internal faults can cause internal short circuits, which can lead to thermal events. Foreign matter that penetrates the separator can create a short circuit, which causes localized heating and further damage to the separator, resulting in further shorting. These faults were highly publicized due to a series of laptop battery fires in 2006-2008, and robust controls must be in place to address them. The risks associated with these defects can be minimized, but the likelihood can never be reduced to zero and appropriate preventive measure should be incorporated to prevent propagation of thermal runaway between cells or modules.” CPSC staff evaluation of scooters sampled at various ports and retail locations in December 2015 and January 2016 showed a marked similarity in scooter electrical systems, including an almost uniform lack of thermal sensing within the battery packs. Also, CPSC staff evaluation of incident samples and review of in-depth investigation reports, revealed a consistent pattern of failure in which the entire battery pack was involved. It appeared that a single initial cell failure resulted in all of the other cells in the pack going into thermal runaway, venting, and initiating a fire. Some of the cells apparently exploded or vented with sufficient force to cause cells or their internal contents to be ejected from the scooter housing over 20 feet away.

Incorporating the test from UL 2580 as proposed will minimize the likelihood of propagation of a cell thermal runaway failure beyond the scooter enclosure.

Item 2:

(New) XXX The electric scooter shall have charger connect-interlock so that the unit cannot be activated when the charger is plugged in.

Rationale: The interlock will prevent the unit from inadvertently switching the unit on while charging and when the rider is not ready. A unit without an interlock may cause consumer injury or fire hazards.

[2] Weicker, Philip, “A Systems Approach to Lithium-Ion Battery Management,” page 37, Artech House, 2014.

(Source: ASTM F2641-08 (Reapproved 2015) *Standard Consumer Safety Specification for Recreational Powered Scooters and Pocket Bikes, Section 5.25*)

Item 3:

> (New) XXXX The electric scooter shall have visual and/or audible indicators and warnings to alert the rider of a low battery condition per ASTM new proposed standard for Electric Self-Balancing Scooters.
> XXXX.1 The warning shall alert the rider when there is less than five minutes of battery operating capacity.
> XXXX.2 A second level alert shall be provided when there is less than two minutes of battery operating capacity. The alert shall be audible and visual. The capacity is based on operation time at maximum current draw for maximum loading conditions.
> XXXX.3 The motor control system shall prevent abrupt stoppage of the motor before the electrical system is completely disabled from a discharged battery.

Rationale: A low battery alert and soft motor shutdown is needed to prevent riders from being injured when a completely discharged battery abruptly causes a scooter to stop. (This is a placeholder for the electrical requirements. The exact times and requirements will be developed in the ASTM and UL collaborative standards development process.)

Item 4:

> 13.3 There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a ~~compound~~ component or subassembly if the distance through the insulation, at voltages above 60 Vdc or above 30 Vrms is a minimum of 0.4-mm (0.02-in) thick for supplementary or reinforced insulation, and passes the Dielectric Voltage Withstand Test, Section 28, and the Isolation Resistance Test, Section 29. There is no minimum insulation thickness requirement for insulation of circuits at or below 60 Vdc or for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation.

Rationale: Editorial

Item 5:

> 23.2 A fully charged sample is to be discharged at a 0.2 C constant discharge rate or a higher discharge rate permitted by the cell manufacturer to the manufacturer's specified EODV. The DUT is then subjected to a constant current charging at the cell manufacturer's maximum specified charging rate and under a single fault condition in the charging protection circuitry that could lead to an overcharge condition. Protective devices that have been determined reliable may remain in the circuit as noted in 19.5. For information purposes, temperatures are to be monitored on the cell/module where temperatures may be highest. The output control circuitry of external chargers with standardized output connectors (e.g. USB connectors) that may result in the use of unspecified chargers shall not be considered as a reliable control to prevent an overcharging condition.

Rationale: Adding the word "cell" in the first and second sentences clarifies that it is the cell manufacturer's specifications.

Item 6:

> 23.3 The test is to be continued until the voltage has reached 110% of the specified upper limit charging voltage or the maximum obtainable charging voltage (if the 110% of specified upper limit charging voltage cannot be reached due to remaining protection circuitry), and monitored temperatures return to ambient or steady state conditions and an additional 2 h has elapsed, or explosion/fire occur. If the DUT is operational after the test, it shall be subjected to a minimum of

one charge/discharge cycle at the cell manufacturer's maximum specified values per Section 21, Post Test Cycle. The test shall be followed by an observation period per 19.7.

Rationale: Adding the word "cell" as indicated in the second to last sentence clarifies that it is the cell manufacturer's specified values.

Item 7:

21.1 Self-balancing scooters that are operational after the following tests shall be subjected to a minimum of one cycle of charging and discharging, or if not operational, subjected to an attempt to charge only in accordance with the manufacturer's specifications to determine that there is no non-compliant results as outlined in Table 21.1 for that test:

a) Electrical Tests - Overcharge, short circuit, overdischarge protection, imbalanced charging;
b) Mechanical Tests - Vibration, shock, drop, crush; and
c) Environmental Tests - Water exposure, and thermal cycling.

Rationale: A consumer will likely try to charge the unit if it does not operate. Therefore, an attempted charge cycle is needed to confirm that charging the battery with a fault in the system will not introduce a hazardous condition.

Item 8:

19.7 Unless noted otherwise in the individual test methods, the tests shall be followed by a minimum 1-h observation time prior to concluding the test and temperatures are to be monitored in accordance with 19.6.

Rationale: More than an hour may be needed for temperatures to return to ambient temperatures or safe conditions. CPSC staff supports the proposed "minimum."

Item 9:

39.1.3 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values per Section 21, Post Test Cycle. The test shall be followed by an observation period per 19.7. except that the observation period will be for a minimum of 48 hours,

Rationale: More than an hour is needed for temperatures to return to ambient temperatures or safe conditions. CPSC staff supports the proposed 48 hours.

Item 10:

16.2 Lithium ion and other lithium based cells shall comply with the requirements for secondary lithium cells in the Standard for Batteries for Use in Electric Vehicles, UL 2580 or CAN/ULC-S2580 or the Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271, or CAN/ULC-S2271. When evaluating the cell and battery control combination, consideration must be given to tolerances in the control circuitry for charging. If the control circuitry settings with tolerances exceed the cell charge specifications for voltage, testing of the cell needs to be repeated with the cell charged to these higher voltage values.

Rationale: Cells should always be maintained within their safe operating region based on the cell manufacturer's specifications. The tolerances should be considered in the evaluation.

Item 11:

39.2.2 The DUT is subjected to immersion in salt water (5% by weight NaCl in H_2O) at a height sufficient to reach the scooter foot support surface. The scooter is partially immersed for 5 minutes.

Rationale: Salt water represents a more stringent test for the electrical system, and it would be consistent for what is used for the immersion test in UL 2271.

Again, thank you for proposing this important standard and providing the opportunity to comment. If you have any questions, or need additional information, please feel free to contact me.

Sincerely,

Douglas Lee

cc: Patricia Edwards, CPSC Voluntary Standards Coordinator