

针刺试验 Nail penetration

- 现有标准-Existing standards
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Existing standards requiring penetration

现有的要求针刺的标准-Existing standards requiring penetration: SAE J2464

4.3.3 Penetration Test (Cell Level or Above)

4.3.3.1 Test Description

Penetrate the DUT with a mild steel (conductive) rod. The diameter of the rod, its end type, as well as the depth and rate of its penetration can be found in Table 5. The orientation of the penetration shall be perpendicular to the cell electrodes. The DUT should be observed for a minimum of 1 h after the test with the rod remaining in place. If parallel cells are used in the Module, the cell level test should be configured with the same number of cells in parallel to the cell that is to be penetrated. When determining the Hazard Severity Level, a spark source should be present to ignite any potentially flammable vent gases or vapors from DUT.

TABLE 5 - PENETRATION CHARACTERISTICS

Size of Test Object	Diameter of Rod	Rod End Type	Rate of Penetration	Minimum Depth of Penetration
Cell	3 mm	Tapered to a sharp point	8 cm/s or greater	Through cell
Module/Pack	20 mm	Tapered to a sharp point	8 cm/s or greater	Through 3 cells or 100 mm whichever is greater

Existing standards requiring penetration

现有的要求针刺的标准-Existing standards requiring penetration: UL-2580

22 Nail Penetration Test

22.1 This test is intended to evaluate the cell's ability to withstand a sudden puncture from a foreign object.

22.2 A fully charged cell shall be subjected to the penetration test in accordance with Electric Vehicle Battery Abuse Testing, SAE J2464.

22.3 As a result of the penetration, there shall be no fire or explosion.

Existing standards requiring penetration

现有的要求针刺的标准-Existing standards requiring penetration: QC/T 743

6.2.12.7 针刺:

- a) 蓄电池按 6.2.4 方法充电。
- b) 用 $\phi 3\text{mm} \sim \phi 8\text{mm}$ 的耐高温钢针、以 $10\text{mm/s} \sim 40\text{mm/s}$ 的速度,从垂直于蓄电池极板的方向贯穿(钢针停留在蓄电池中)。蓄电池应符合 5.1.11g) 规定。

The battery is fully charged.

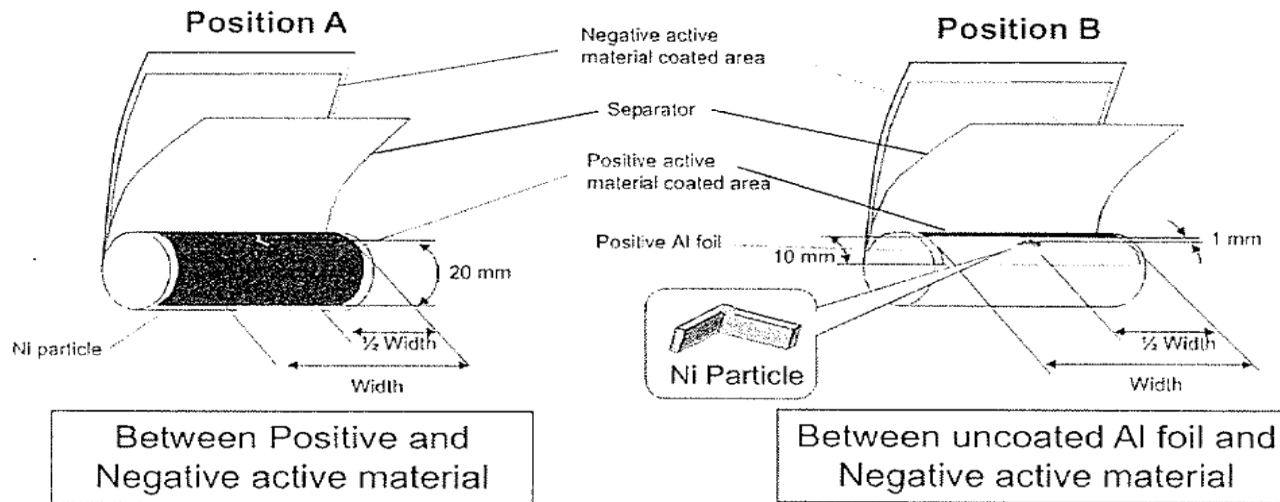
Use a high-temperature-resistant steel needle whose diameter is 3mm-8mm to prick the battery module at a speed of 10mm/s-40mm/s vertically to the battery plate. The needle should penetrate at least 3 cells and remain in the battery.

The battery should not explode or catch fire.

Existing standards requiring penetration

现有的要求短路的标准-Existing standards of internal resistance: JIS 8714

1. Charge the cell up to the upper limit charging voltage (e.g. 4.25V)
2. Disassemble the cell and take out the winding core.
3. Insertion a Nickel particle to the core.



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Mechanisms of nail penetration

- 针刺实验能够很好地反应内短路的发生。
- Nail penetration can well reflect the happening of the internal short circuit(ISR).

Yamaushi的研究表明，针刺实验过程中瞬间释放的热量主要来自于电池内部短路。针刺造成的内部短路将会持续发生，直到整个电池内部的电能被释放完全。

It is suggested that the thermal runaway in the nail penetration tests is determined by the total amount of Joule heat produced by the large current due to the internal short circuit until the discharge of the whole electrode is completed [1].

针刺实验有助于改进电池的安全性设计。

...These phenomena need to be taken into consideration in the battery design.

Tobishima 等人指出，针刺实验是模拟内短路非常重要的手段。

The nail penetration test is very important and is considered to simulate an internal short in a cell [2].

[1] Y. Yamauchi, K. Mizushima, Y. Satoh, S. Yamada. Development of a simulator for both property and safety of a lithium secondary battery. J. Power Sources. 2004 (136): 99-107.

[2] S. Tobishima, K. Takei, Y. Sakurai, et al. Lithium ion cell safety. J. Power Sources, 2000, 90(2): 188-195.



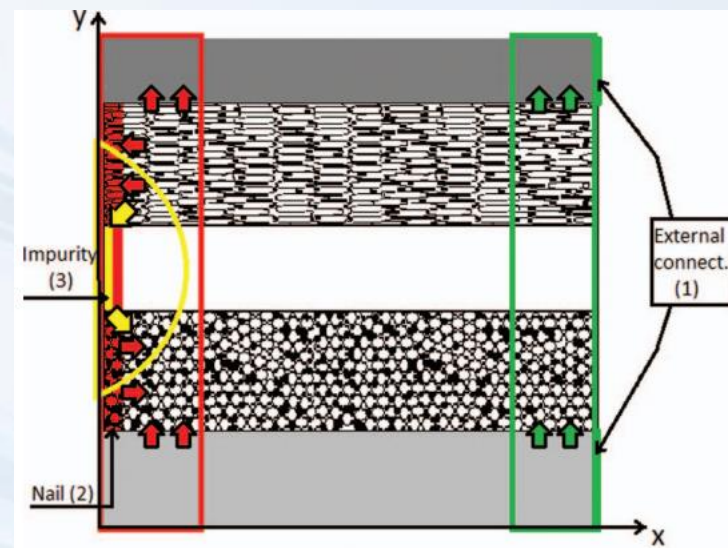
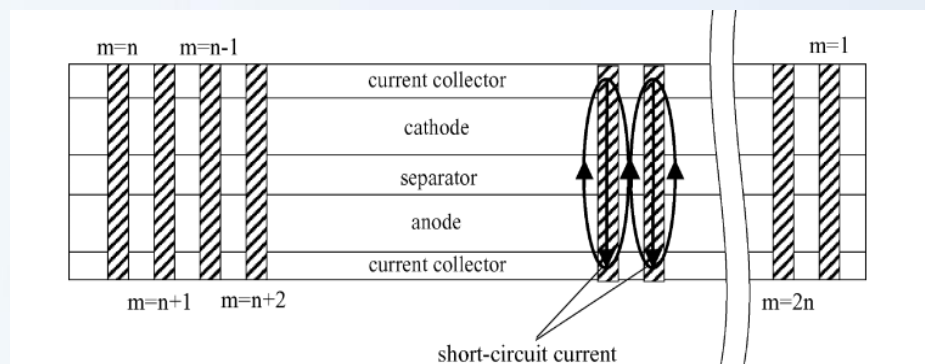
Mechanisms of nail penetration

当针刺入电池时，电池内部形成多个短路通路。

When a nail penetrates lithium-ion battery, the internal short circuit may occur at $2n$ regions of the electrode sheet wound n times in the cell .

针刺同时包括了内短路和外短路的两个过程。

The electrical energy would be released during a penetration test though both internal short circuit (ISC) and external short circuit (ESC). ISC and ESC would happen together.



Foundations of Nail penetration

- 实际情况中，存在异物刺入电池包内部导致电池发生内外短路的可能。

Penetration is possible during accidents. Metallic objects can fiercely penetrate into the battery pack causing SR(short circuit)-induced thermal runaway.

- 针刺实验能够很好地反应内短路的发生。

Nail penetration can well reflect the happiness of the internal short circuit(ISR).

- 针的刺入提供了电池内部短路的通路，电池的内外短路在针刺时同时发生。

The current of internal short circuit and external short circuit can both get through the pass provided by the penetrated nail.

Foundations of Nail penetration

- 针刺实验时，由电能转化的热能存储于电池内部，电池能量短时间集中释放，实验条件比单纯内、外短路更为严格。而且更易于操作

The nail penetration test is severer than the pure ISC and ESC.

Also easy to operate

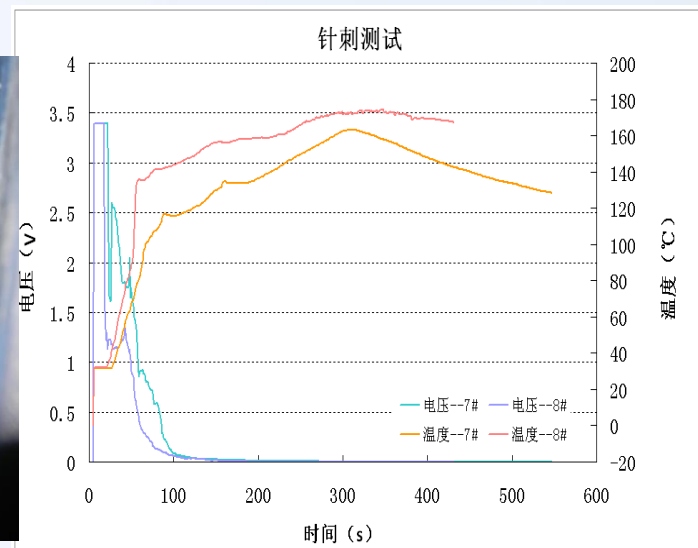
- 更严格的测试标准将大大减少安全性事故的可能

Severer test can reduce the possibility of serious accident. It can also reduce the possibility of the recall of the sold cars.

- 通过电池材料、设计的改进，高能量的锂离子电池是能够通过针刺实验的。

Li-ion battery can pass the penetration test by solid improvements of the battery design.

Nail penetration test



针刺试验后解剖电池隔膜的穿孔处状态:穿孔处隔膜变薄、透明化,与针接触的边缘有部分融化现象。少量极粉脱离极片,粘到隔膜。

可以很好的模拟内短路的情况

The state of the membrane after nail test: the perforation membrane become thin and transparent, and some membrane melt at the edges of contact with the needle. A small amount of powder fall off from the plate and stick to the membrane. Simulate the internal short circuit simulation excellently .

Procedure of Nail penetration

Test procedure:

The battery is fully charged. Use a high-temperature-resistant steel needle whose diameter is 5mm-8mm to prick the battery module at a speed of $25\text{mm}/\pm 5\text{mm}/\text{s}$ vertically to the battery plate. The needle should penetrate at least 3 cells and remain in the battery.

Requirement: No explosion, no fire.

