

The logo for Shmuel De-Leon Energy Ltd is a green rectangular box. On the left, the text "Shmuel De-Leon" is stacked above "Energy Ltd" in a white, sans-serif font. On the right side of the box, there is a faint, light-colored illustration of a battery or energy storage device.

Shmuel De-Leon
Energy Ltd

What can we Learn from the Samsung Galaxy Note7 Battery Safety Event

June 2018

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Samsung Galaxy Note7 Smartphone Recall



- Launch globally date: August 19, 2016
- Device discontinued globally: October 11, 2016
- Product name: Samsung Galaxy Note7 smartphones
- **Hazard:** Lithium-ion battery in the Galaxy Note7 smartphones overheat and catch fire, posing serious fire and burn hazard to consumers.
- **Units: 1.9 Millions**

Samsung Note7 Incidents/Injuries

- 96 reports of batteries in Note7 phones overheating in the U.S.,
- Samsung has received 13 reports of burns and 47 reports of property damage associated with Note7 phones.



The Galaxy Note 7 implicated in dramatic Jeep and house fires, reports say



iPhone Mobile Phone Battery Explosion 2016



An Apple iPhone 6 exploded in cyclist's pocket

“I saw smoke coming out of my back pocket... I was completely bewildered about what it was. All of a sudden I felt a surging pain in my top right leg. I heard a kind of a snap and I could feel the thing melting through my shorts”.



Moli Energy – Lithium Metal Battery Explosion - 1989

- Moli Energy Canada was the first to mass produce lithium metal rechargeable 18650 cells on 1988
- Used in Cellular phones in Japan
- Explosion of a cellular phone battery in the face of a customer lead to a recall of 1.5M cells in 1989
- Shown to be safe in the lab
- Root Cause – Lithium metal plating during charge – Dendrites that led to a short circuit and thermal run away
- The recall and compensation to injures lead to bankruptcy of the company



Sony Laptop Battery recall 2006



P/N

Lot Number

Cost for Sony: 1B\$ estimate

7 million 18650 cells affecting 6 PC makers

These lithium ion batteries can overheat, posing a fire hazard to consumers

Nokia Recall Cell-phone Batteries 2007



Cost for Nokia: 150M\$ estimate

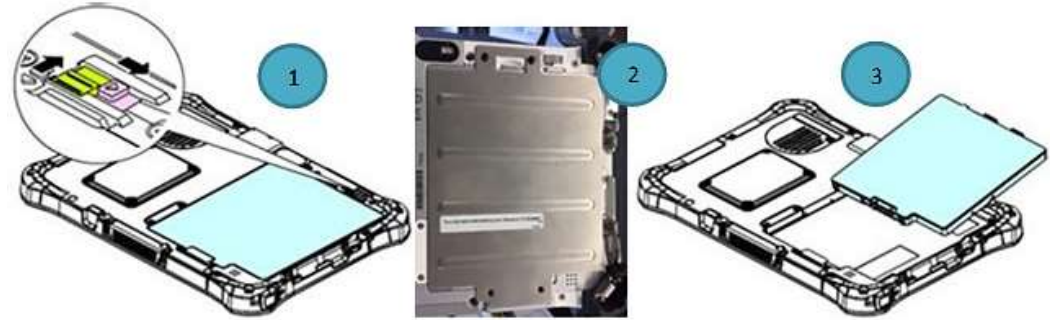
**BL-5C Panasonic batteries to have internal short circuit
These lithium ion batteries can overheat, posing a fire
hazard to consumers**

Boeing Dreamliner Battery Fire 2013



Cost for Boeing: 600 M\$ estimate
Expected smoke event: 1 every 10 millions flights hours
Cause: Internal short circuit in one cell

Panasonic Recalls 280K Tablet Battery Packs Due to Fire Hazard



March 2017 - Cost for Panasonic: TBD

Can short circuit after a prolonged use in extreme temperatures.

16 reports of combusted battery packs between March 2017 and April 2017

Why that is happened?

External Short circuit

Internal Short circuit

- Particle
- Dendrites
- Separator failure
- Impact/puncture

Overcharge

Overdischarge

External Heating

Mechanical Damage

Elevated Temperatures
Generate Heat

Heat Dissipation <
Heat Generation

Thermal Run Away

Vent, Flaming Vent

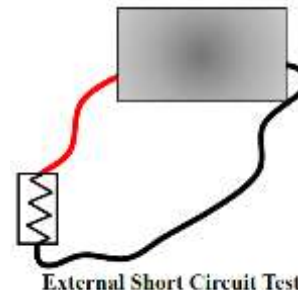
Rupture

Fire

Heat Dissipation >
Heat Generation

Safe!!!

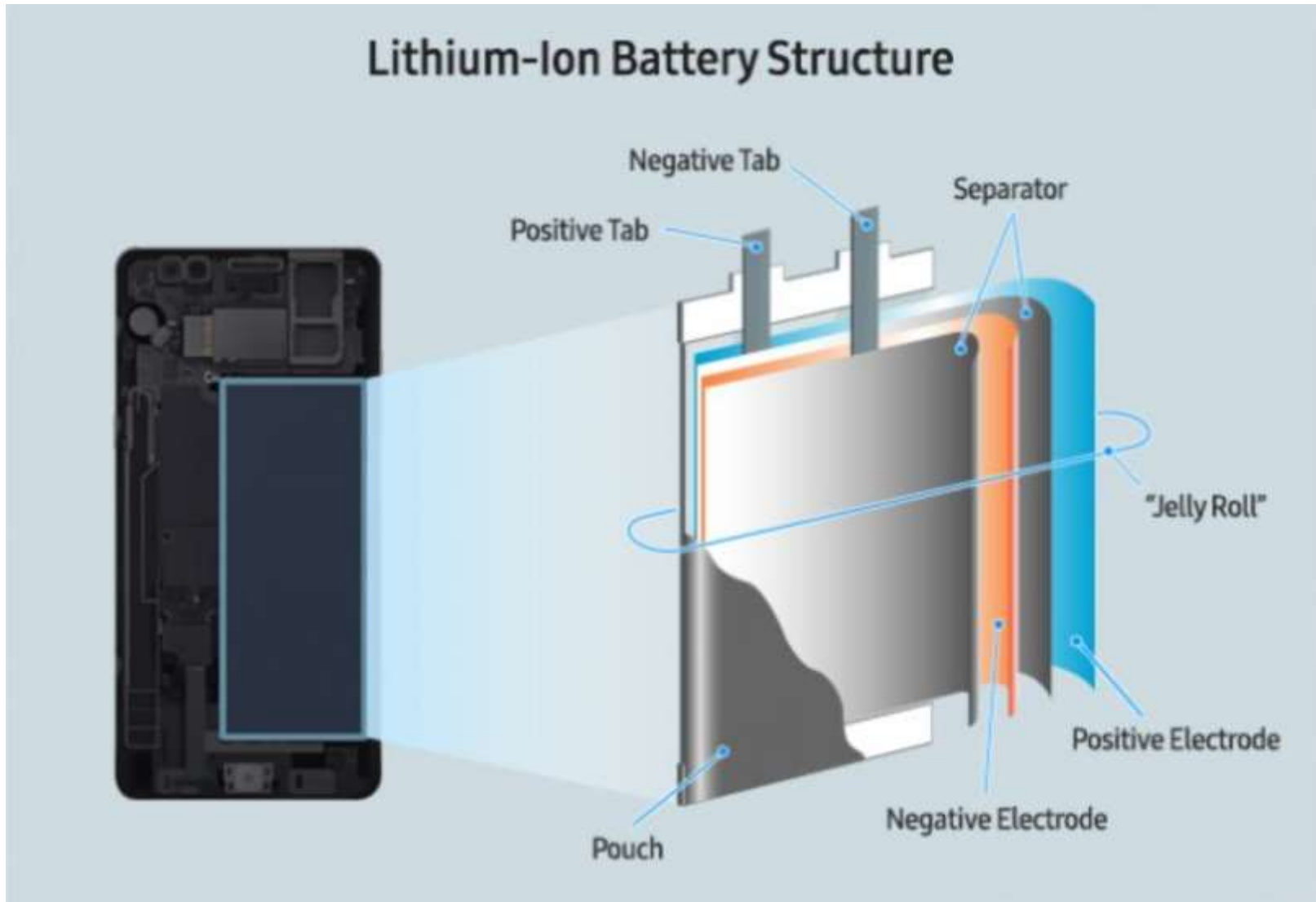
Leaking of
Noxious or acid
gasses, Strong
acids,
Flammable
gasses and
liquids



What Cause the Samsung Galaxy Note7 Safety Problems

- **Samsung didn't disclose officially the battery safety root cause till 1/2017 – My personal assumption was:**
- **Samsung used a high energy cathode for maximizing the battery energy density**
- **Thin separator was used for freeing volume for more active materials**
- **Charging the battery cause some sort of lithium metal plating as a dendrites at the end of charge – May be due to fast charging capability of 10 min charge for 4 hour battery run time**
- **On some cases lithium dendrites penetrate the thin separator and cause Internal short circuit, heat and fires**

Li-Ion with Wound Internal Construction



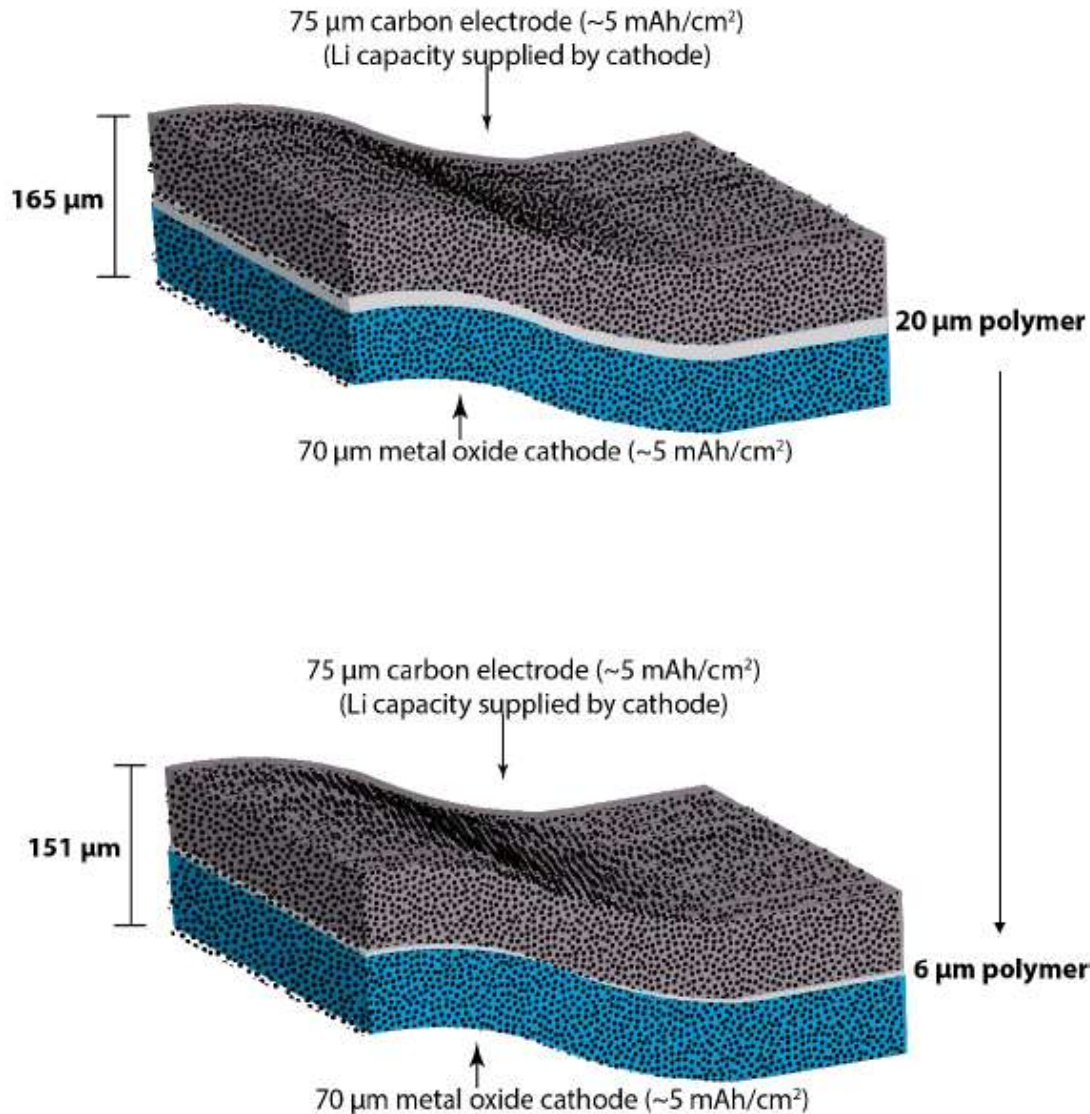
Samsung Galaxy Note 7 Battery Hold an Impressive 3,500mAh Despite its Slim Profile



An estimation of 250 Wh/kg and 700 Wh/l at cell level – that is the highest energy densities known for smart phone batteries !!!



Pushing the limits...



Li-ion manufacturers have been desperate to improve energy density. This led several of them to reduce cell volume by moving to dangerously thin polymer separators. In hindsight the minimal improvement in energy density was hardly worth the resulting incidence of cell phone fires.

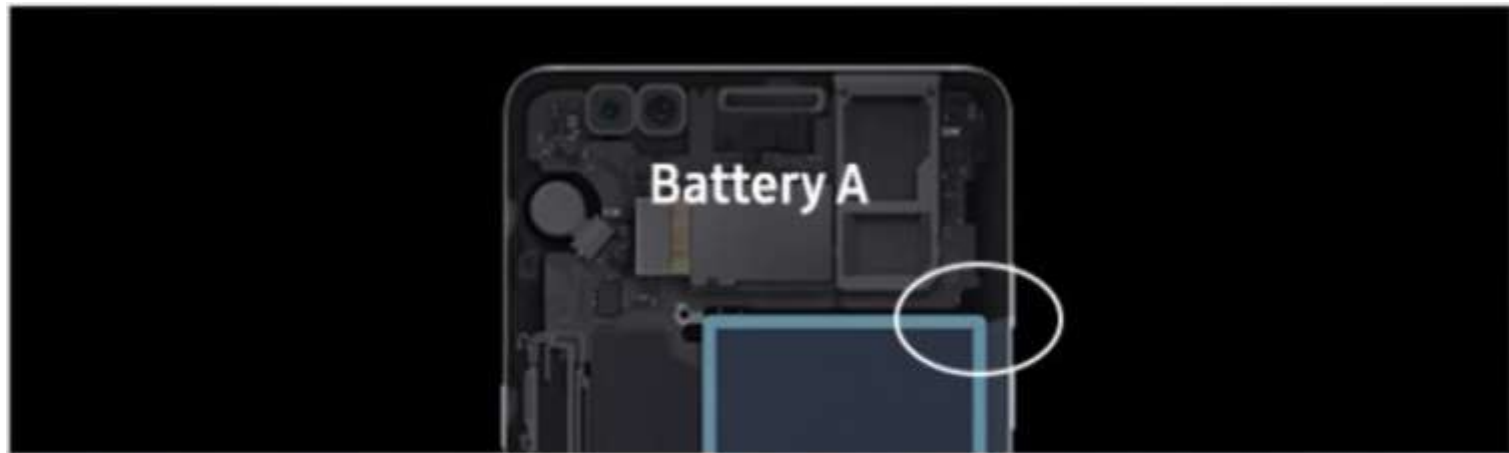
Samsung Reaction

- **2/9/2016 First recall of Galaxy Note7 used Samsung Korea made batteries and replaced it by Galaxy Note7 used ATL china made batteries (65/35 supplier split Samsung SDI/ATL)**
- **15/9/2016 After reports of the same safety events with the Galaxy Note7 used ATL china made batteries Samsung halted that recall**
- **Then Samsung stop marketing the Note7 and to concentrate on full worldwide recall for not taking any extra risks for customers safety**
- **Samsung start with internal investigation supported also by 3rd experts**

Samsung took the responsibility

Samsung Official Investigation Results 22/1/2017

- **Over 700 researchers and engineers spent months analyzing 200,000 Note 7 devices and 30,000 Note 7 batteries**
- **Samsung conducted an internal review and sought independent reviews from UL, a safety science organization, Exponent, a US-based consulting and engineering firm and TuvRheinland, a German-based company**
- **The battery was the cause for the fires**
- **Internal short circuiting in Galaxy Note 7 batteries caused the phones to heat up and catch on fire**



Abnormal

Normal

Main Cause



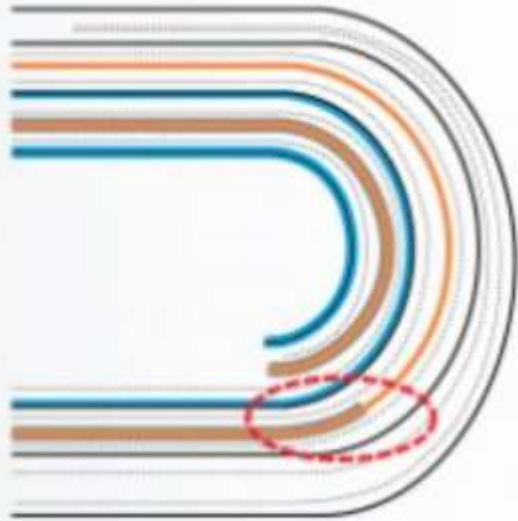
The negative electrode was deflected in the upper-right corner of the battery



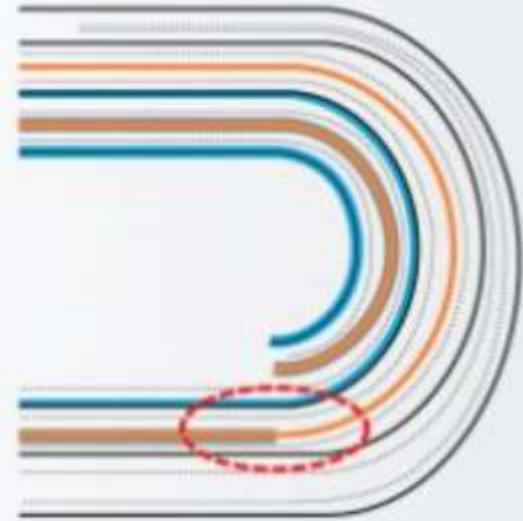
The negative electrode is not deflected

There was an issue with the upper right hand corner of the battery cell. “The main cause for the incidents was deflections in the negative electrodes

Additional contributing factor

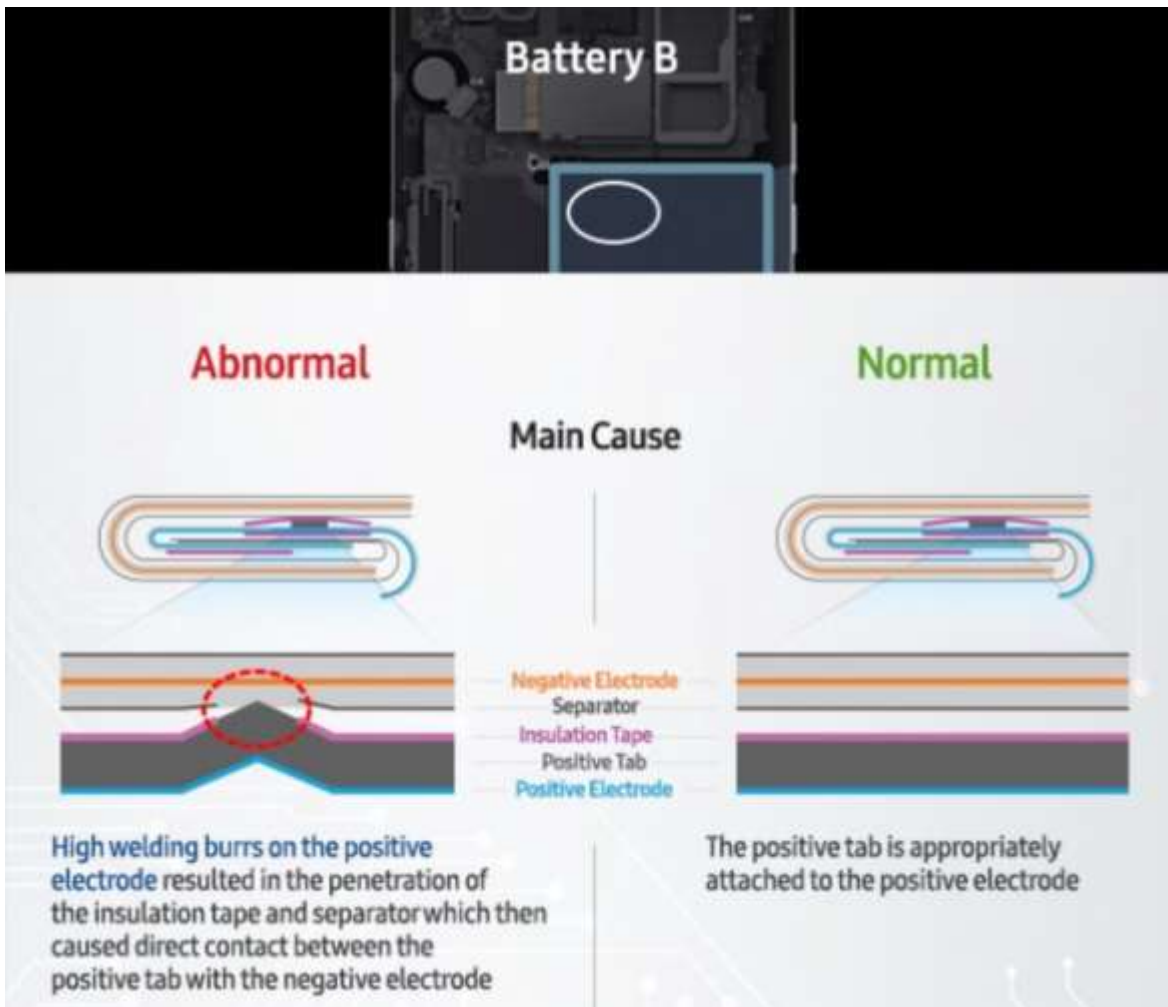


The tip of the negative electrode was incorrectly located in the curve, not the planar area

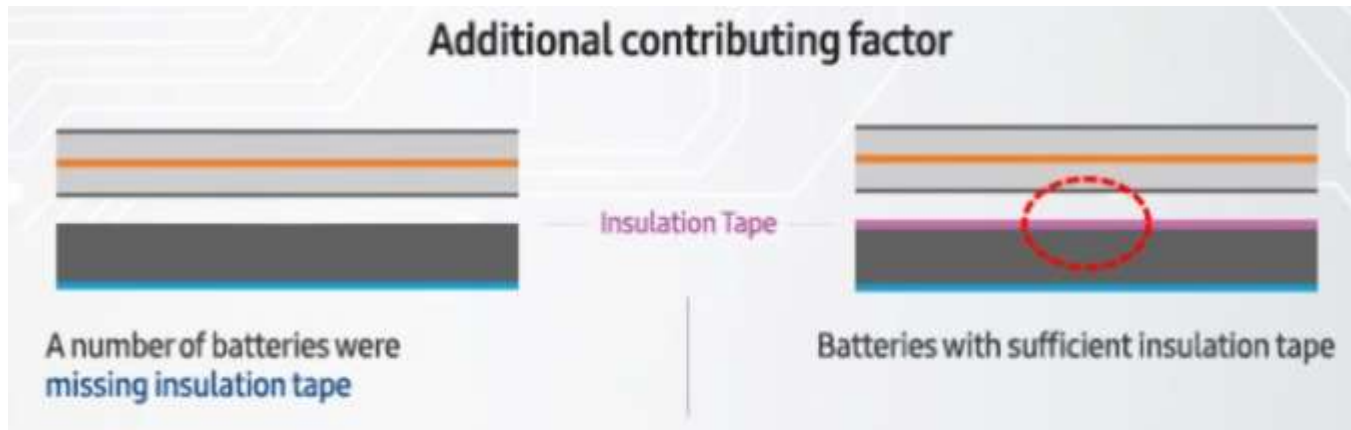


The tip of the negative electrode is correctly located within the planar area

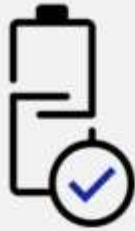
-adding incorrect positioning of the negative electrode tip also led to a higher likelihood of incidents



melted copper on the negative electrode area. There were welding issues that led to contact between the positive and negative layers, resulting in short circuits



- **Samsung said it has improved its processes and faults would not happen again**
- **Samsung said it has developed a battery check protocol and has invited researchers and academics to provide analysis to ensure battery safety**
- **In a bid to regain customer confidence, Samsung said it implemented a range of quality control and safety measures for their handsets, including an 8-point battery safety check**



Durability Test

It starts with enhanced battery testing, including overcharging tests, nail puncture tests and extreme temperature stress tests.



Visual Inspection

We visually inspect each battery under the guideline of standardized and objective criteria.



X-Ray

We use X-ray to see the inside of the battery for any abnormalities.



Charge and Discharge Test

The batteries undergo a large-scale charging and discharging test.



TVOC Test

(Total Volatile Organic Compound)
We test to make sure there isn't the slightest possibility of leakage of the volatile organic compound.



Disassembling Test

We disassemble the battery to assess its quality, including the battery tab welding and insulation tape conditions.



Accelerated Usage Test

We do an intensive test simulating accelerated consumer usage scenarios.



ΔOCV Test

(Delta Open Circuit Voltage)
We check for any change in voltage throughout the manufacturing process from component level to assembled device.

- **Samsung said 96 per cent of 3 million devices sold and activated globally had been returned**
- **Samsung took a \$US5.3 billion loss from its operating profit due to the Note 7 debacle - one of the worst technology recalls in recent times**



Koh Dong-jin, president of Samsung Electronics' Mobile Communications Business, speaks during a news conference at its headquarters in Seoul to summarize findings on a review of the disastrous launch of the Galaxy Note 7. (Kim Hong-Ji/Reuters)

What Should We Learn?

- Battery safety event damage could be huge and not proportional to the battery cost
- Damage is higher as the device market is larger or device mission is critical (Like in Space or Military)
- Passing UM, IEC, UL testing certifications didn't find the safety failures
- Companies with no deep pockets will may bankrupt because of battery safety event damage
- Batteries are not just another component and there is a need to understand them from all aspects including the safety before designing them into a device

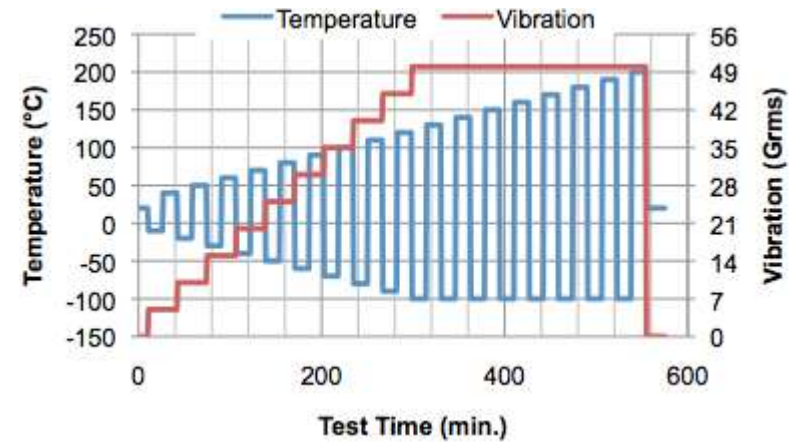
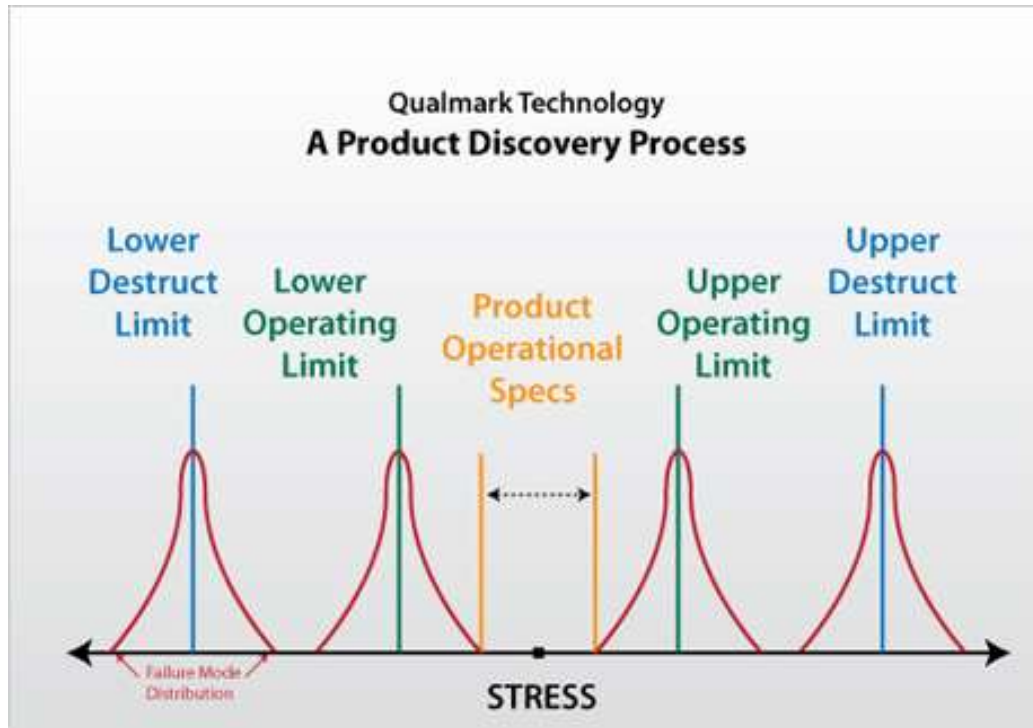


Recommendations

- Cells/batteries makers should review and improve their cells/batteries safety validation process
- Testing for specs are not sufficient and shouldn't be the only safety validation process
- HALT-HASS testing methodology can add to the cells/batteries robustness and make them safer
- Based on the potential damage a battery safety validation process should be apply on 2 separate independent labs
- Running several months internal operation pilot before marketing starts

In the race for performance we shouldnt forget Safety!!!

Halt (Highly Accelerate Life Testing) – Hass (Highly Accelerate Stress Screening)



Halt-Hass Process

- Battery testing affects human lives by enforcing performance and safety standards.
- Halt-Hass tests use combined testing scenarios in a testing chamber to stress simulate failure modes.
- Running Halt-Hass process to a battery can ensure passing easily battery testing standards (UN, J2464, UL2054, UL1642, IEC 62660-2...)



Thank You for Your Attention



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Information for presentation obtained by:

1. Public web sources.
2. Shmuel De-Leon Battery/Energy Sources DataBase ® (Includes 29000 cell PDF data sheets) <http://www.sdle.co.il/Default.asp?sType=0&PageId=45580>

Battery Testing Halt-Hass Machines - Safety

Standard Halt-Hass machines are not safe for battery testing. Machines should custom made them with several special safety features to make them suitable for battery testing.

Halt-Hass Machines Safety Features

- **Safety Door Interlock - Prevents entry either during tests or after an event** □ **Custom Pressure Relief Vent - Protects chamber from a sudden release of high pressure gas** □
- **External Lights - externally mounted lights eliminates potential spark source**
- **Fresh Air Exchange System - Aids in removing all gases from inside the chamber prior to opening the door**
- **Temperature Limited Sheath Heaters - Standard ni-chrome wire heaters can reach temperatures of +540°C (+1000°F). Temperature is set below ignition temp. of gases** □
- **Intrinsically Safe Barriers - Prevents the potential of high voltage pulses**

Halt-Hass Machines Safety Features

- **Gas Monitors - O₂, H₂, CO, etc - Can be interlocked to controller to shut down chambers** □
- **Protective Enclosure/Structure - External structure that would contain any fire or explosion** □
- **Non Sparking Fan Blades or Blower Wheels - Prevents sparking/explosion** □
- **Fire Suppression-Inert Atmosphere Uses N₂ or CO₂ to eliminate Oxygen - does not prevent thermal runaway but can help contain** □
- **Reinforced Chamber Floor - To support weight of heavy product and extreme temperature** □
- **LN₂ Test Article Surface Cooling - Used to cool cells or packs if they overheat - may help prevent thermal runaway** □

Halt-Hass Machines Safety Features

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- **GN2 Purge - Helps flush out outgassing from product under test**