Battery Incident Root Cause Analysis

and Review the Certifications

Nov. 14, 2017

Jaesik Chung Ph.D.
Hwansu Park, Kwang Jung,
James Park, and Randy Ortanez

PCTEST Engineering Laboratory

Contents

1.Battery Incident History, Root Cause Analysis and Corrective Action

- Recalls of Lithium-ion Battery Products (2012-2017)
- Battery Incidents examples
- 2004 Phone Battery Issues_ Root cause Analysis and Corrective Action
- 2006 Dell NBPC Recall, Root cause Analysis and Corrective Action
- Boeing 787 Dreamliner Battery Incident & Corrective Action

2.Galaxy Note 7 Battery Incident History, Root Cause Analysis and Corrective Action

3.Review the IEEE 1725 & CTIA Certification

Recalls of Lithium-ion Battery Products (2012-2017)

Consumer Product Safety Risk Management System (CPSRMS) searched incident reports from 1/1/12 to 7/24/17 using Narrative field search terms:

LI-ION/LITHIUM/POLYMER/BATTER/CHARG

Results: > 25,000 incident reports; 483 primary product codes

CPSRMS Incident Data (2012-2017)

Product	# of Incidents
Computer battery or charger	3,000
Cell phone battery or charger	2,000
Power Banks (Portable USB charger)	400
Drones (under DOT)	200

Root Causes
–Battery Management System (BMS)
–Cell manufacturing quality control (QC)
–Lack of system integration (Charger-BMS-Cells)
–Non-Listed cells/systems

49 Recalls (U.S.) of LiB - Powered Products

Product	# of Recalls	# Device
Hoverboard	11	502,200
Laptop	11	498,162
Flashlight/Lantern	3	18,305
Tablet	2	83,000
Power Bank	4	211,325
Charger	3	684,007
Battery Backup	1	2500
Jumpstarter	2	14814
E-Bike	1	5000
UPS	1	2876
Cell Phone	1	1,920,927
Other*	9	289,692
Total	49	4,232,808

* Other products include baby monitor, gloves, hand warmers, RC car battery pack and wireless speakers

*** Reference: Doug Lee, US CPSC at the Battery Show, Novi MI Sept.11 2017**

PCTEST ***Battery Safety & Reliability Lab.***

3

Battery Incidents examples : E-Cigarette, Hoverboard

CPSC E-Cigarette Fire and Explosion Data
(Food and Drug Administration Jurisdiction)

•Through 2016 –34 Emergency room visits (NEISS*)
–29 Explosions, 5 Fires
•Location of Battery or E-Cigarette Device
–23 In pocket (19 Batteries), 4 In hand, 3 Near thigh, 2 In Face, 1 Near eye, 1 In car charger
•Injuries
–32 burns –1 electrical, 4 chemical, and 27 thermal; 2 Lacerations

Incidents from Self-Balancing Electric Scooters or Hoverboards

•Over 200 fire incidents since 2015, causing over $4M in property damages
–Incidents occurred in 43 states
–During and after charging
–During and after riding
•3 Deaths –1 fire (2 victims, young girls), 1 fall
(First responder motor vehicle death excluded)

Hoverboard Evaluation Results

•Inadequate BMS –Failed protective circuit safety analysis.
•Inadequate cells (pack) for system loading.
•Cells not certified to standards to ensure cells are manufactured to best practices
•Battery chargers not certified to appropriate standard, UL 1310, UL 1012, UL 60950-1
•Wiring improperly secured and protected in the pivot base, exposed connections
•> 500,000 units recalled

*** Reference: Doug Lee, US CPSC at the Battery Show, Novi MI Sept.11 2017**

PCTEST ***Battery Safety & Reliability Lab.***

4

2004 Phone Battery Issues_ Root cause Analysis and Corrective Action

Most important corrective action was to generate the IEEE 1725 and CTIA certification Program.

2003 ~ 2004 Many Cell phone models had many battery issues in the field caused by many kinds of root-causes.

Many phone makers had a big headache by the fake batteries.

Industry needed a standard Guideline for the LiB safety.

IEEE1725: 2006 was published. IEEE Standard for Rechargeable Batteries for Cellular Telephones.

IEEE 1725: 2011 (Revision of IEEE1725:2006) was published.

IEEE 1725 Battery Safety Standard

IEEE STANDARDS ASSOCIATION IEEE

Livium™

IEEE Standard for Rechargeable Batteries for Cellular Telephones

IEEE Power Engineering Society

Sponsored by the
Stationary Batteries Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

10 June 2011

IEEE Std 1725™-2011
(Revision of
IEEE Std 1725-2006)

CTIA Battery Safety Certification

CTIA Certification
A Division of CTIA-The Wireless Association®

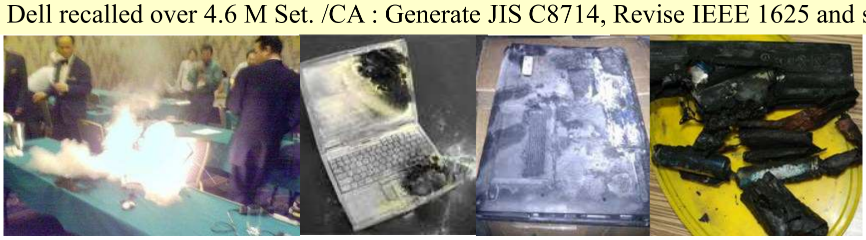
Certification Requirements for Battery System Compliance to IEEE 1725

June 2015

Revision 2.9

2006 Dell NBPC Recall, Root cause Analysis and Corrective Action

Dell recalled over 4.6 M Set. /CA : Generate JIS C8714, Revise IEEE 1625 and start CTIA Certification.



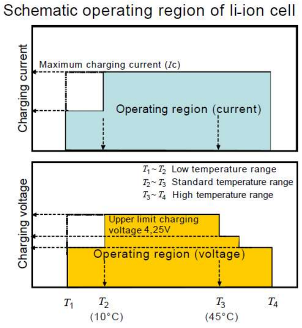
Laptop Battery Recall : Y 2006

Aug. 15: Dell, 4.2 ~ 4.6 M
Aug. 25: Apple , 1.8 M
Sept. 19: Toshiba, 340 K
Sept. 29: IBM-Lenovo: 526 K
Oct. 05 : Fujitsu 300 K

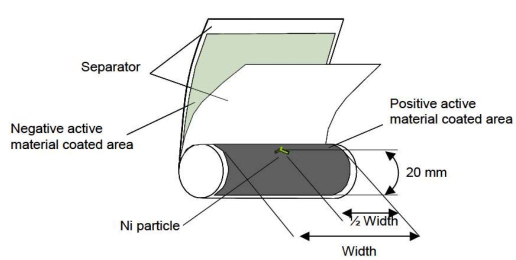
*** Cell & pack were certified by UN DOT(IEC62281), IEC 62133, UL 1642/ 2054, National Standard**

BAJ _ Guidance for Safe Usage of portable Rechargeable LiB Pack

Schematic operating region of li-ion cell

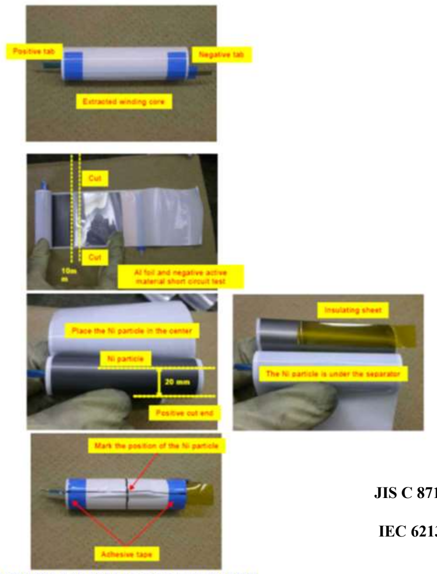


Develop Forced Internal Short : JIS C 8714

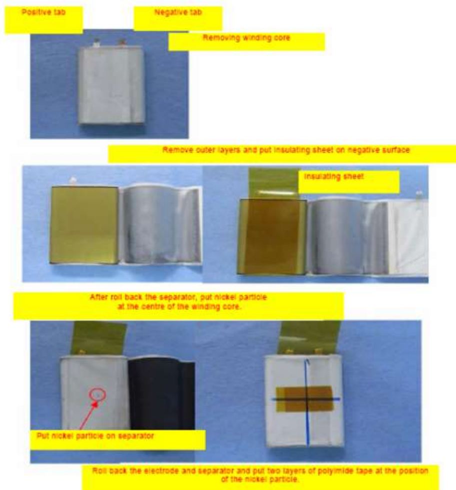


Corrective Action-2_Japan_ Forced Internal Short_ JIS C 8714

Cylindrical Cell



Prismatic Cell

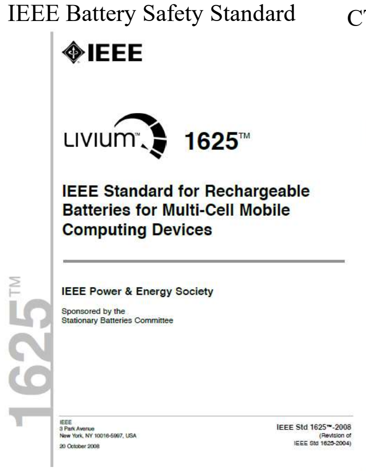


JIS C 8714, Safety Tests for Portable Lithium Ion Secondary Cells and Batteries for Use in Portable Electronic Applications,
IEC 62133: Secondary Cells and Batteries Containing Alkaline or Other Non-acid Electrolytes -Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made from Them, for Use in Portable Applications

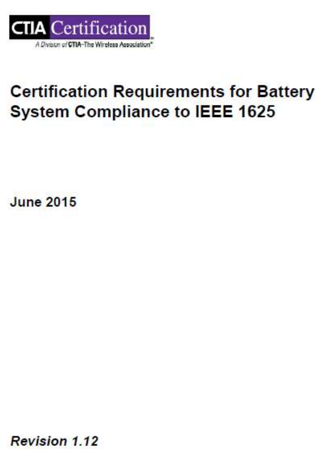
Corrective Action-2: IEEE Standard and CTIA Certification

Most important corrective action: Amendment of IEEE 1625 and initiate CTIA certification Program.

IEEE Battery Safety Standard

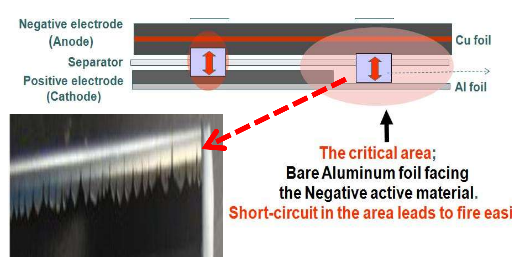

IEEE
LIVIUM 1625™
IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices
IEEE Power & Energy Society
Sponsored by the Stationary Batteries Committee
1625™
IEEE Std 1625™-2008 (Revision of IEEE Std 1625-2004)

CTIA Battery Safety Certification


CTIA Certification
A Division of CTIA-The Wireless Association
Certification Requirements for Battery System Compliance to IEEE 1625
June 2015
Revision 1.12

Provide a guideline for the best practices for the Design, Material selection, Manufacturing and Quality control, Test, Audit and Certification for the LiB safety.: cell, pack, charger, host, system, accessary, user, environment.

Internal Short Avoidance :IEEE 1625/1725

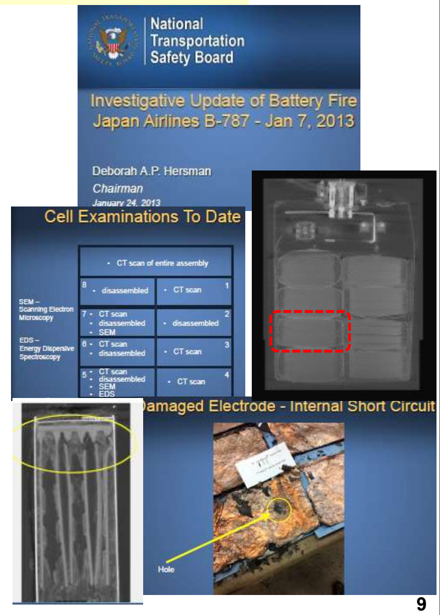


Reference – IEEE 1625_2008

PCTEST Complete Wireless Lab www.pctestlab.com

Boeing 787 Dreamliner Battery Incident & Corrective Action

NTSB leaded the root- cause Analysis / Corrective Action was done by Boeing and their suppliers.



Investigative Update of Battery Fire Japan Airlines B-787_Boston Logan Airport: Jan 7, 2013
National Transportation Safety Board (NTSB) _Deborah A.P. Hersman / Jan. 24, 2013

Two cargo-plane crashes are suspected of fires stemming from packages of batteries:

1) Sept. 3, 2010: UPS Boeing 747 caught fire after leaving Dubai and crashed: > 81,000 Li batteries .
2) Feb. 7, 2006: UPS McDonnell Douglas DC-8 as it approached Philadelphia: fire broke out aboard
3) Mar. 1991 ~ Oct. 9, 2012: FAA counted 132 air incidents involving travelers' batteries burning through luggage, catching fire and occasionally hurting people.

PCTEST Complete Wireless Lab www.pctestlab.com

Contents

1. Battery Incident History, Root Cause Analysis and Corrective Action

2. Galaxy Note 7 Battery Incident History, Root Cause Analysis and Corrective Action
- History of Note 7 Battery Issues
- Public Report_ Root cause Analysis and Corrective Action
- Root Cause Analysis Result
- Corrective Actions
- Review the Analysis Reports

3. Review the IEEE 1725 Standard & CTIA Certification

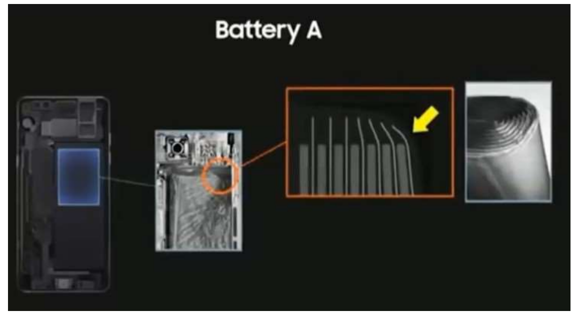
History of Note 7 Battery Issues

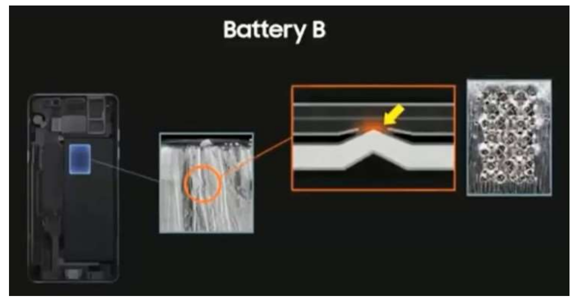
Aug. 19, 2016: Global Launching
Sept. 02, 2016 : Replacement
Oct. 11, 2016 decide Discontinue
Jan. 23, 2017 Report failure investigation & CA

Failure investigation
:700:Engineers, 200K:Devices, 30K:Batteries

- -Fast Charging
- -Wire & wireless charging
- -Waterproof
- -Electrostatics: USB type-C-port
- -Iris scanner
- -Software effect
- -Manufacturing and logistics process Analysis
- -Power consumption and heat generation

Systematical and scientific root-cause Analysis broad and well-designed corrective action !

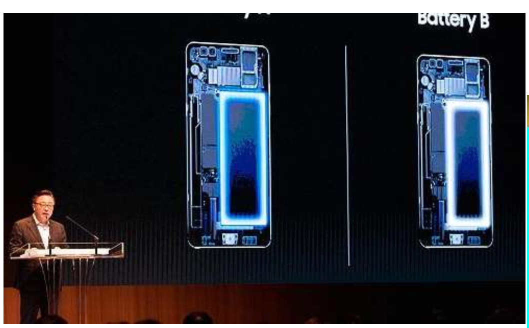




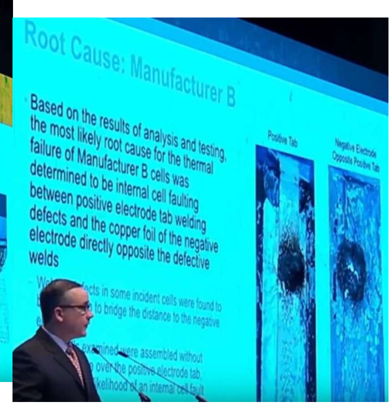
On 23 Jan 2017, Samsung Reported their failure investigation results // https://www.youtube.com/watch?v=Iu18CykEH9o

Public Report_ Root cause Analysis and Corrective Action

Samsung hired 700 engineers to test out 200k Note 7 devices and 30k batteries, and engaged external investigators from independent safety science company UL, Exponent and TUV Rheinland to probe the issue.



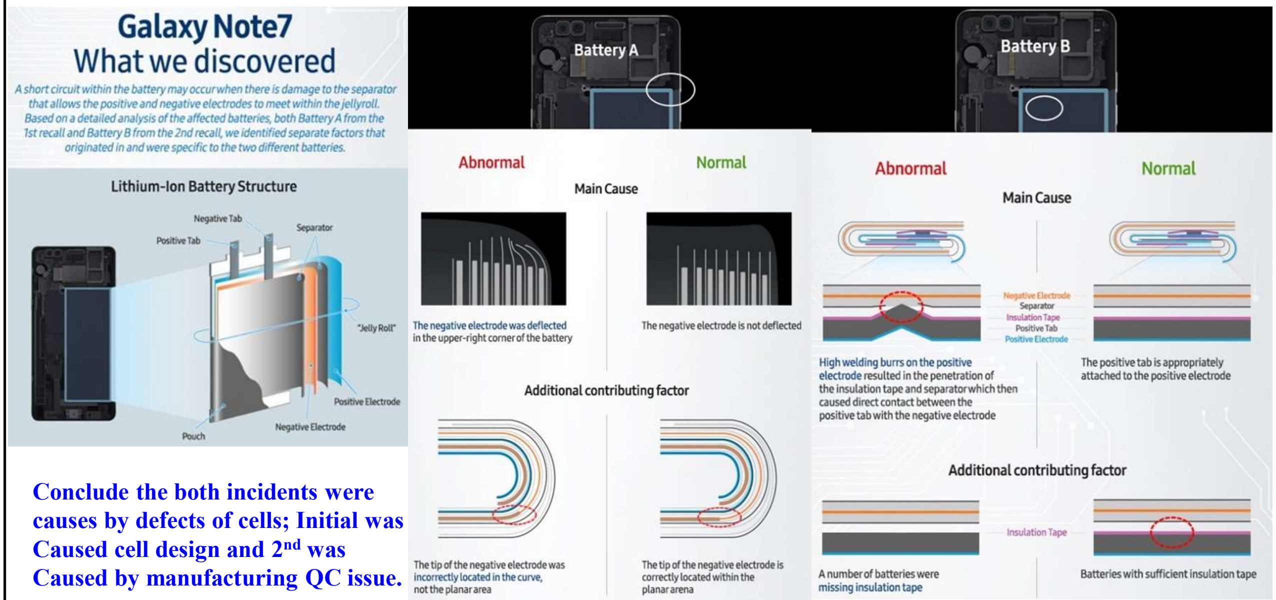
Well organized, systematical and scientific root-cause Analysis and broad and well-designed corrective action was done by Samsung and their Partners and suppliers.



On 23 Jan 2017, Samsung Reported their failure investigation results
https://www.youtube.com/watch?v=Iu18CykEH9o

PCTEST Complete Wireless Lab www.pctestlab.com

Root Cause Analysis Result



Conclude the both incidents were causes by defects of cells; Initial was Caused cell design and 2nd was Caused by manufacturing QC issue.

PCTEST *Battery Safety & Reliability Lab.*

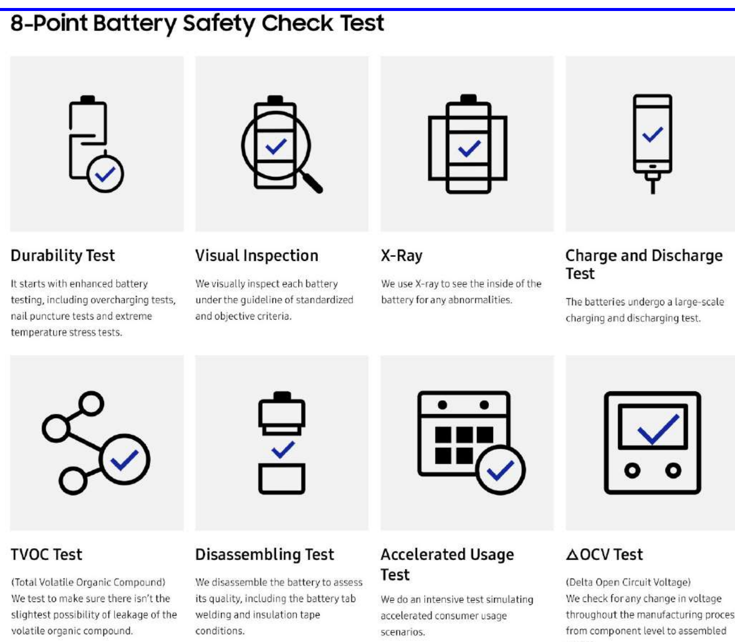
On 23 Jan 2017, Samsung Reported their failure investigation results. //https://www.youtube.com/watch?v=Iu18CykEH9o

13

PCTEST Complete Wireless Lab www.pctestlab.com

Corrective Action -1: by Samsung and their suppliers

8-Point Battery safety Check Test



Well organized and managed Corrective Action were token broadly by Samsung and their suppliers

* Reference: Samsung Report- Business Insider- Jan23 2017

PCTEST *Battery Safety & Reliability Lal*

14

Corrective Action- 2 by CTIA Certification

1. Added new Test item to verify cell charging ability at lower (- 5 °C) and Higher (60 °C) Temperature.

2. Drop test of the Embedded pack should be performed at a Host System level.

3. Enhanced the check of the "Cell Dimensional Allowance" pack & host device.

4. Amend IEEE 1725 to adopt new technology and usage environment.

5. Will update and upgrade the CTIA Certification after IEEE 1725 Amendment.

New test item on IEEE 1725 Cell Certification

4.54 External Short Circuit Test of Temperature Cycled Cells

Reference: N/A

Purpose: To validate the ability of a cycled cell to withstand an external short circuit.

Procedure: 5 Cells, as below, shall be shall be cycled 25 times at the maximum charge/discharge rate specified by the cell manufacturer. Test shall start and end with the cells being fully charged.

Cell Samples	Chamber Temperature (± 2°C)
5	Minimum charge temperature specified by cell manufacturer
5	Maximum charge temperature specified by cell manufacturer

The cycled cells are rested at Ambient Temperature for a period of 24 hours before the commencement of the short circuit test.

Each test sample cell, in turn, is to be short-circuited by connecting the positive and negative terminals of the cell with a circuit load having a resistance load of 80 +/- 20 milliohms. The cell is to be discharged until a fire or explosion is obtained, or until it has reached a completely discharged state of less than 0.1 volts and the cell case temperature has returned to ±10°C of the elevated chamber ambient temperature (i.e. 55 ± 5°C).

Compliance: No fire, no explosion, and maximum temperature less than 150 °C.

Corrective Action- 3 by CPSC Recommendations to IEEE1725

Related to the company A – Design issue

5.4 Cell core assembly
– (new) Corner clearance validation process
5.4.1.3 Detection of damaged cores
5.5.6 Cell Aging
5.5.7.1 Testing procedures
5.6.6.2 Dissection of cycled cells
– (new) verify 4 corner radius (prismatic)
– (new) verify top and bottom of core (cylindrical)

Related to the company B – QC issue

5.5.6 Cell Aging
5.5.7.1 Testing procedures
5.6.6.2 Dissection of cycled cells
– (new) verify electrode tab welds
– (new) verify insulation tape at tabs in key areas
– (new) verify insulation tape at electrode ends
– (new) verify insulation tape at radius

9.2 User Interactions and Responsibilities (information to user)
– (new) Remove from front and back pants pocket when sitting
– (new) Cases are recommended to protect the phone from physical damage

(new) External forces requirement: drop, impact, and flexing test requirements
– Dissection of tested units

- Global review to update referenced standards and technology changes

*** Reference: CPSC proposal at the CTIA Meeting-Apr.11 2017**

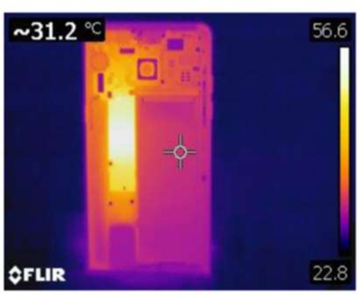
Review the Analysis Report

Of the UL and Exponent

for the Host System Base

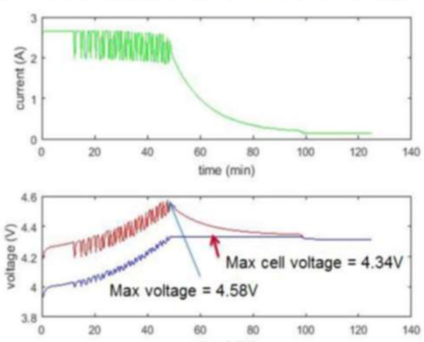
Battery System Analysis by UL

- Note 7 components do not increase the battery cell temperature to a level higher than the specified threshold



* Reference: Samsung Report- Business Insider - Jan. 23 2017

- Note 7 maximum current drain meets the specifications provided by Samsung
- The maximum charging current, the maximum temperatures and the maximum cell voltage are within the specifications with the standard adapter provided by Samsung



CTIA Certification check electrical, mechanical and thermal function during1) Pack and 2) Host + System in connection with Battery safety.

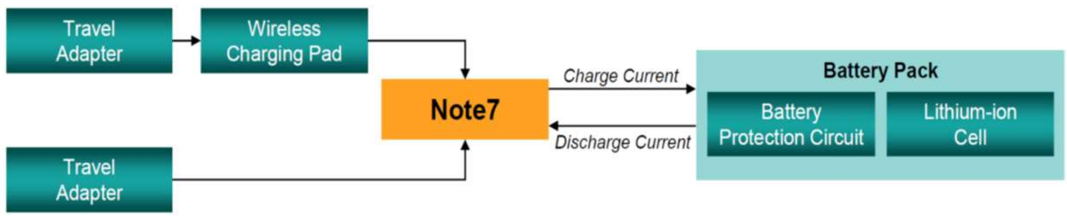
PCTEST Complete Wireless Lab www.pctestlab.com

Battery System Analysis by Exponent

- Analysis of the Note7 battery system design indicated that the system is designed with multiple levels of protection for the Li-ion cell
- The testing and analysis performed did not identify a fault in the Note7 battery system that could have triggered the observed battery failures in the field
- Testing performed with several third party wireless charging pads available for use with the Note7 device showed that the Note7 device is designed to prevent a failure of these charging pads from causing the Li-ion cell to operate outside its specifications

Note7 Battery System Architecture

* Reference: Samsung Report- Business Insider - Jan. 23 2017



CTIA Certification check electrical, mechanical and thermal function during1) Pack and 2) Host + System in connection with Battery safety.

PCTEST Complete Wireless Lab www.pctestlab.com

Review the Analysis Report

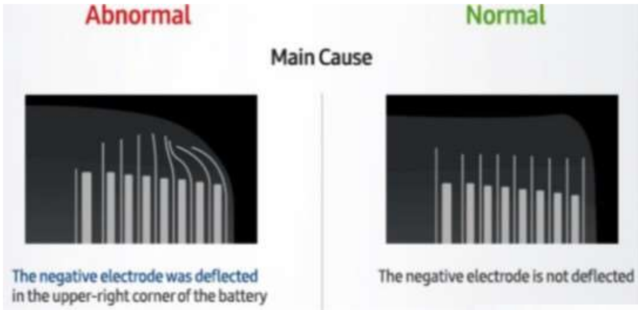
of the UL and Exponent

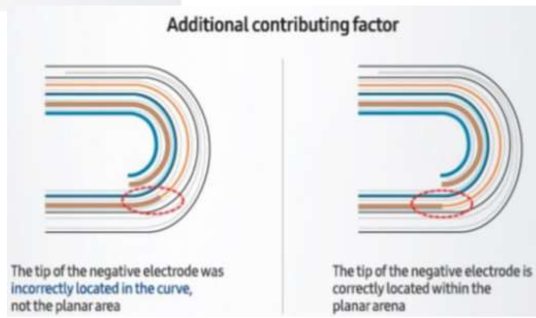
for the Cell Maker: Company- A

PCTEST Complete Wireless Lab www.pctestlab.com

Manufacturing A: Design Issue

Exponent





* Reference: Samsung Report Business Insider-Jan23 2017

PCTEST *Battery Safety & Reliability Lab.*

21

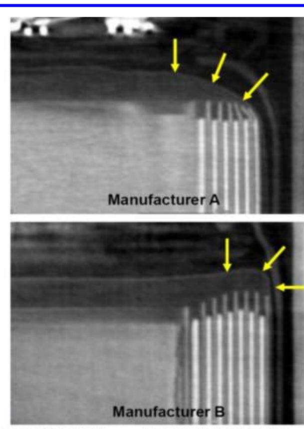
PCTEST Complete Wireless Lab www.pctestlab.com

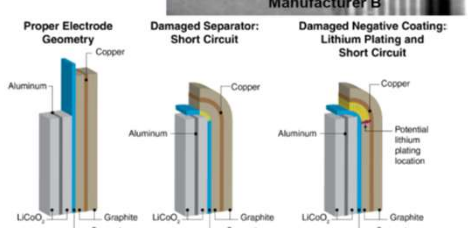
Manufacturing A: Design Issue

Exponent

Root Cause: Manufacturer A

- Based on the results of analysis and testing, the most likely root cause for the thermal failure of certain Manufacturer A cells was determined to be unintended damage to the negative electrode windings consistently in the corner of the cell closest to the negative tab
  - The unintended damage was present in all of the cells examined by Samsung and Exponent
  - The damage was caused by a cell pouch design that provided inadequate volume to accommodate the electrode assembly
  - The observed damage provides multiple potential routes to internal cell faulting and thermal failure with normal cycling, including compromise of the separator and lithium plating
- Exponent's initial analysis of cells from Manufacturer B showed no deficiencies in the pouch, design or manufacturing
  - Manufacturer B cells manufactured after our initial investigation was complete were shown to contain a distinctly different defect that was not present in the initial cells we investigated



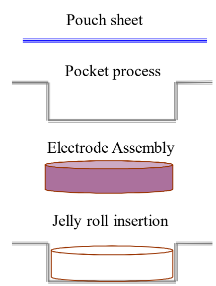


* Reference: Samsung Report- Business Insider-Jan. 23 2017

PCTEST *Battery Safety & Reliability Lab.*

Comment

Pouch pocket manufacturing process and Jelly roll insertion process



Check Point:
- Pressure check during the insertion process
- Check the anomaly on Jelly roll after cell sealing process.

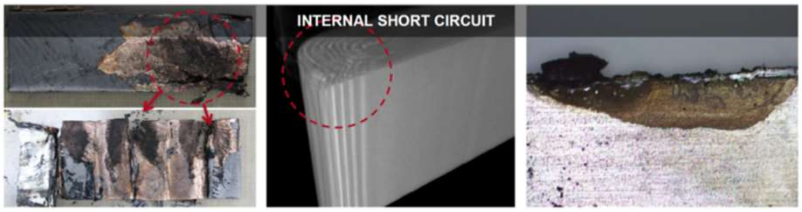
Example of a Pouch pocket manufacturing process

22

Assessment – Company A

UL

- Signs of internal short circuit (ISC) at the upper right corner of the cells from 6 damaged devices
- Signs of ISC at the upper right corner of 4 swollen cells



- Samples show a similar pattern of deformation at upper corners. Upper right corner deformation appears to be deeper than upper left.
- Tear down analysis shows repeating deformation areas on separator at the corner locations.

Assessment – Company A

UL

1) There may be multiple contributing factors relating to battery assembly/manufacturing and design that when combined led to the failure of the Note 7 in the field.

a) Battery assembly/manufacturing: Deformation at the upper corners
b) Battery design:
- Thinner separator could lead to poorer protection and reduced tolerance to manufacturing defects
- Higher energy density in general can exacerbate the severity of a battery failure.

2) One major failure mechanism is likely:
A combination of deformation at the upper corners + thin separator + repeating mechanical stresses due to cycling, causing higher possibility of separator damage leading to an ISC between aluminum and copper foil at the corner

3) Additional investigation is needed to understand the root-cause of the deformations at the upper corners

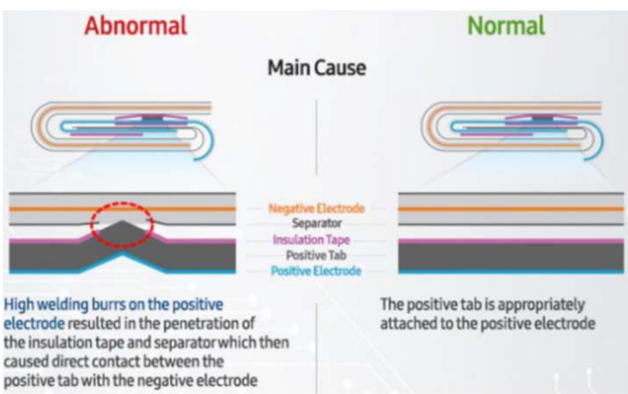
Review the Analysis Report

of the UL and Exponent

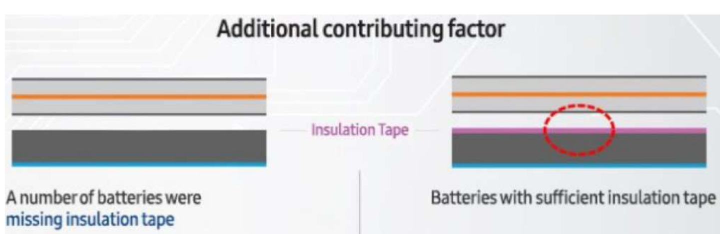
for the Cell Maker : Company- B

Manufacturing B: QC Issue

Exponent



Check insulation tape status 100% vision check is mandatory during the manufacturing process. QC checks it every batch and many inspections.



* Reference: Samsung Report-Business Insider-Jan. 23 2017

Manufacturing B: QC Issue

Exponent

Root Cause: Manufacturer B

- Based on the results of analysis and testing, the most likely root cause for the thermal failure of Manufacturer B cells was determined to be internal cell faulting between positive electrode tab welding defects and the copper foil of the negative electrode directly opposite the defective welds
  - Welding defects in some incident cells were found to be tall enough to bridge the distance to the negative electrode foil
  - Some cells examined were assembled without protective tape over the positive electrode tab, increasing the likelihood of an internal cell fault

Positive Tab

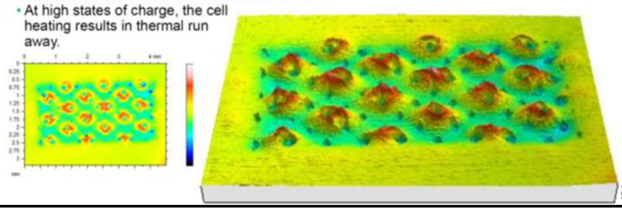
Negative Electrode Opposite Positive Tab

Comment

* IEEE 1725 and CTIA Certification Requirement
:Regularly Check the operating condition of the ultrasonic welding machine and evaluate the Welding position of Electrode:

1) Operator.: Check two samples per lot.
2) QA: Check electrode, bur and Insulation

- Poorly controlled welding of the positive tab in Manufacturer B cells creates sharp, relatively tall welding defect features
- Normal swelling and contraction of the electrodes during charge and discharge forces the weld defect features into the opposing negative electrode
- Short circuit between the weld defect feature on the positive tab and the copper of the negative electrode results in heating of the cell
- At high states of charge, the cell heating results in thermal run away.



* Reference: Samsung Report-Business Insider-Jan23 2017

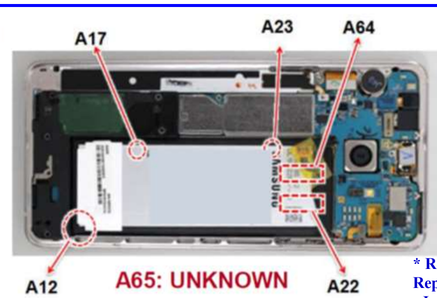
PCTEST ***Battery Safety & Reliability Lab.***

27

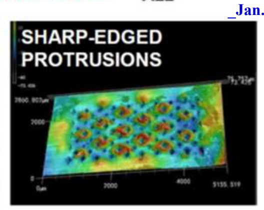
Key Findings – Company B

UL

- Signs of internal short circuit (ISC) at different locations of the cells from 5 of the damaged devices
- Signs of ISC at the tab locations of swollen cells
- Missing insulation tape on the cathode of swollen cells
- Sharp-edged protrusions on the tab welding spots of swollen cells



* Reference: Samsung Report : Business Insider _Jan. 23 2017



Comment These kind of issues can be filtering out during Formation and Aging process in the cell manufacturing Process.
These kind of issues can be filtering out during cell approval test inside the cell manufacturing factory.
These kind of issues can be filtering out during the Certification test; 1) UN 38.3 Manual test, 2) UL 1624, and 3) IEEE 1725 Certification, CRD 4.2, 5.50, 4.52 // 4) and During manufacturing Site Audit

PCTEST ***Battery Safety & Reliability Lab.***

28

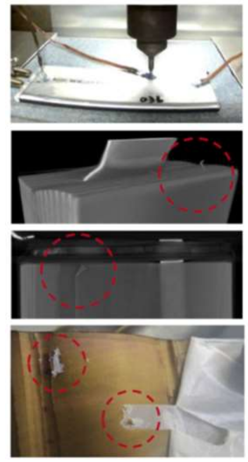
Key Findings – Company B

UL

1)The failure mode (ISC in winding edge) observed in field event samples can be reproduced by UL's ISC or localized heat pad tests

2) Flaws were readily found from 3D CT scan of some samples

3)Tear-down analysis findings include:
- Uneven charge status on multiple samples
- Signs of internal short circuit
- Poor alignment and inconsistent shape and dimension of tabs and insulation tapes
- Sharp edge protrusion of welding joints



* Reference: Samsung Report- Business Insider - Jan. 23 2017

Assessment – Company B

UL

1) **No evidence of device-level compatibility issues that may have contributed to the failure of the Note 7 in the field.**

2) There may be multiple contributing factors relating to production quality and battery design that when combined led to the failure of the Note 7 in the field.

A. Production quality:

a) Missing insulation tape on tab could result in higher possibility of ISC
b) Bigger protrusion of welding points in tab could lead to higher possibility of separator puncture
c) Misalignment of insulation tape and/or tab could bring more risk of ISC

B. Battery design:

a) Thinner separator could lead to poorer protection and reduced tolerance to manufacturing defects
b) Higher energy density in general can exacerbate the severity of a battery failure

3) One major failure mechanism for field incidents is likely:
The combination of **(a) missing insulation tape + (b) sharp edged protrusions on tab + (c) thin separator,** all leading to a high possibility of an ISC between cathode tab and anode, subsequently resulting in heating and fire.

4) Further analysis is needed to understand the root-cause of the damage to the edge/corner of the battery which results in ISC at that location

* Reference: Samsung Report- Business Insider - Jan. 23 2017

PCTEST Complete Wireless Lab www.pctestlab.com

Contents

PCTEST Complete Wireless Lab www.pctestlab.com

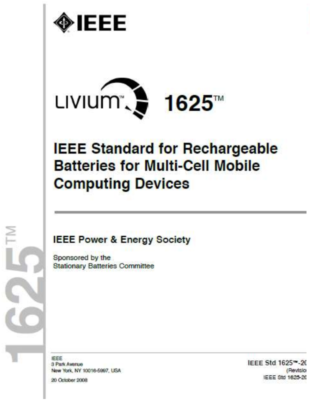
Review the IEEE 1725 Standard and CRD/CRSL/PMD Certification documents relate to the Galaxy Note 7 Battery Incident

* CRD : Certification Requirement Document
* CRSL : Certification Requirement Status List
* PMD : Program Management Document

PCTEST Complete Wireless Lab www.pctestlab.com

Document: IEEE Standard and CTIA Certification

IEEE Battery Safety Standard


IEEE

1625™

IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices

IEEE Power & Energy Society

Sponsored by the Stationary Batteries Committee


IEEE STANDARDS ASSOCIATION

IEEE Standard for Rechargeable Batteries for Cellular Telephones

IEEE Power Engineering Society

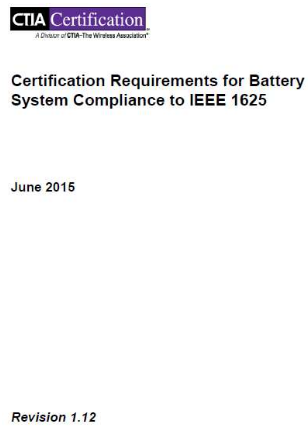
Sponsored by the Stationary Batteries Committee

IEEE 3 Park Avenue New York, NY 10016-5997 USA

10 June 2011

IEEE Std 1725™-2011 (Revision of IEEE Std 1725-2006)

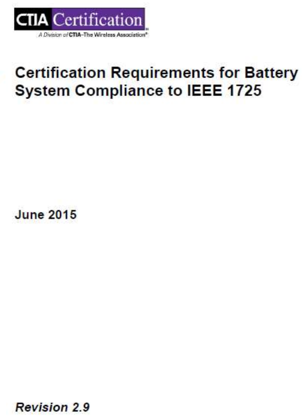
CTIA Battery Safety Certification


CTIA Certification

Certification Requirements for Battery System Compliance to IEEE 1625

June 2015

Revision 1.12


CTIA Certification

Certification Requirements for Battery System Compliance to IEEE 1725

June 2015

Revision 2.9

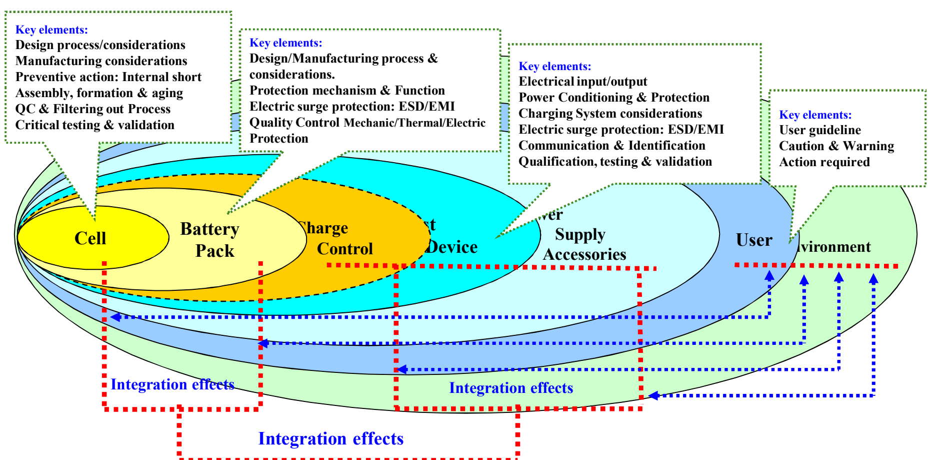
PCTEST ***Battery Safety & Reliability Lab.***

PCTEST Complete Wireless Lab www.pctestlab.com

Concept of the IEEE Standard and CTIA Certification

Safety & Reliability of Cell, Pack and Charger + Effects of System Integration

Verification of System Integration effects on IEEE 1625/1725



*** Pre-requirement: UN DOT certificate, IEC62133/UL1642 test report, ISO-9000 Certificate.**

PCTEST ***Battery Safety & Reliability Lab.***

CTIA Certification from the IEEE1725

Select just "Shall" clause, not accept "Should" clauses from the IEEE1725

5.4 Cell core assembly
All processes referenced in this subclause apply to assembly of the cell core. For example, the cell core is the structure formed by the spiral winding or stacking of electrodes and separator.

5.4.1.3 Detection of damaged cores
Manufacturer **shall** have a method to detect nonconforming cell cores. Methods may include high-voltage dielectric test (high-pot), voltage test, resistance/impedance test, and/or aging.

5.5.6 Cell aging
The manufacturer/supplier **shall** develop and apply appropriate cell aging, grading, and/or sorting criteria for post-assembly screening of cells to identify and eliminate early failures and to identify weak cells. The manufacturer shall show the process is in control and shall identify and record any performance variations for each production lot.

5.5.7.1 Testing procedures: The manufacturer **shall** randomly sample 100 cells of a given type from one day's production after completion of manufacturer's normal aging process. The 100 cells are then fully charged according to the manufacturer's specification. Their VOC shall be greater than 95% of the manufacturer's fully charged voltage specification. After one day of storage at room temperature, measure VOC1, then soak the cells for one week at 45 °C, and return cells to room temperature for one day and measure the VOC2 for all cells. Determine the average ΔV [Equation (2)] for all 100 cells where ΔV is the difference between the initial VOC measured after one day of storage and the VOC after soak and return to room temperature [Equation (1)].

5.6.6.2 Dissection of cycled cells : The manufacturer/supplier **should** dissect at least five cycled cells and verify the absence of lithium plating. Pass criteria: No excess lithium observed.

CRD Review _ **the areas where have higher latent safety risk**

Guideline for Insulation and protection the areas where have higher latent safety risk of internal-short circuit in the electrode assembly.

4.12 Application of Insulation

Reference: IEEE 1725, Section 5.2.5.1

Purpose: Reduce the potential of short circuit by ensuring the proper insulation of the internal cell tab.

Procedure: Verify on 5 samples that the insulation scheme (may contain multiple components) continues until it reaches the point of attachment to the cell terminal. Not applicable to the cells that have more than one single tab at cell core initiation (such as stacking or folding configurations).

Compliance: Tabs with opposite polarity as the enclosure shall be insulated from its electrode assembly (electrodes and separator) exit point until it reaches the point of attachment to the cell terminal.

4.13 Application of Insulation

Reference: IEEE 1725, Section 5.2.5.1

Purpose: Reduce the potential of short circuit by ensuring the proper insulation of the internal cell tab.

Procedure: Visually inspect the placement of tab insulation scheme (may contain multiple components). Compare the observations with vendor's cell specifications. Not applicable to the cells that have more than one single tab at cell core initiation (such as stacking or folding configurations).

Compliance: Insulation exists and complies with vendor's cell specification unless demonstrated by documented evaluation report.

4.14 Application of Supplementary Insulation

Reference: IEEE 1725, Section 5.2.5.1

Purpose: To confirm compliance to the requirement for supplementary insulation where only a single separator layer exists adjacent to the internal tab.

Procedure: Analyze 5 units for isolation of tab from the opposite electrode. Not applicable to the cells that have more than one single tab at cell core initiation (such as stacking or folding configurations).

Compliance: Additional insulation has been used if only a single layer of separator isolates the tab from the opposite electrode.

4.25 Burr Control

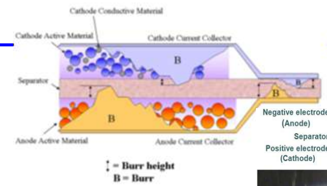
Reference: IEEE 1725, Section 5.3.6

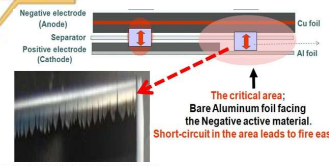
Purpose: To ensure that the tolerance on burr height is controlled to limit the potential for internal shorts. This is not applicable if design prevention is present.

Procedure: Confirm design parameters to the reference. Using inspection data, confirm that the manufacturing process is in control. This is not applicable if design prevention is present.

Compliance: Inspection data shows compliance to specified tolerances. For those cases where an out of control condition was noted, action was taken. This is not applicable if design prevention is present.

4.24 Burr Control





4.37 Internal Short Avoidance

4.36 Internal Short Avoidance

Reference: IEEE 1725, Section 5.5.1

Purpose: To ensure that the method of assembly for insulating material (whether for electrode, current collectors, or internal insulation) is designed to provide reliable protection against latent shorts for the product lifetime of the cell.

Procedure: Lab to tear down 5 fresh samples and verify proper insulation placement. Lab to review insulating material specifications in regards to stability of the material's insulating property over time.

Compliance: Validate that all likely material interfaces that may result in a latent internal short are insulated. Validate the method of assembly for insulating material properties is sufficient to provide protection from shorts over the projected lifetime of the cell.

4.40 Integrity of Cell Core Assembly

Reference: IEEE 1725, Section 5.5.3

Purpose: To ensure that the integrity of the electrodes is verified through resistance or continuity check or equivalent means.

Procedure: Confirm product specification to inspection parameters. Validate that an effective real time (Hi-Pot or equivalent) 100% testing process is in place.

Compliance: Validate test procedures and test parameters. Verify test parameters via review of engineering documentation. 100% testing is required.

Validate that an effective real time (Hi-Pot or equivalent) 100% testing process is in place.

4.43 Electrode Alignment: conduct 100% inspection to ensure no damage is caused by the case insertion process. Polymer cells shall be inspected via a vision system either prior to or following complete assembly.

4.44 Cell Aging and Validation of Aging Process

4.46 Care During Cell Assembly : Tab Welding

4.47 Qualification of New Cell Designs / 4.48 Qualification of Production Cells

4.50 Cell Thermal Test / 4.52 Evaluation of Excess Lithium Plating and Short-Circuit Test on Cycled Cells

Qualification process:

IEEE 1725 & CTIA Certification has Qualification process for the new & production, cell/pack/Host Device.

These clauses can prevent and filter out the latent safety risky design and product through their internal process.

4.47	**Qualification of New Cell Designs**	**To ensure that the cell qualification processes have been properly characterized, optimized, controlled, and continuously improved. Additionally, to ensure that all cells are required to pass such tests before being given production status.**
4.48	**Qualification of Production Cells**	**To establish production cell qualification and periodic re-qualification requirements.**

5.44	**Qualification of New Pack Designs**	**Ensure new pack designs have passed specified tests identified by the vendor before qualification as a production pack.**
5.45	**Qualification of Production Packs**	**To establish that qualification requirements continue to be met throughout production, and are properly characterized, optimized and controlled.**

6.34	**Qualification of New Host Device Designs**	**Ensure new host device designs pass specified tests identified by the vendor before qualification as a production host.**
6.35	**Qualification of Production Host Devices**	**Ensure production host devices pass qualification tests at specified intervals.**

PCTEST Complete Wireless Lab www.pctestlab.com

Activities of CTIA Certification after the Galaxy Note 7 Battery incident

1. Update the IEEE 1725 Standard

: Start the IEEE 1725 Amendment: adopt New Technologies & usage condition

2. Update CTIA Certification program
   1) Upgrade CATL capability
   2) update all documents: CRD, CRSL and PMD
   3) Upgrade Cell Manufacturing Site Audit
   4) Upgrade Cell Design Process and Qualification process

PCTEST Complete Wireless Lab www.pctestlab.com

Conclusion

Root-Cause Analysis and Corrective Action for the battery incident of the Galaxy Note 7 done by Samsung and their partners had shown the best practices of the Root-Cause Analysis and Corrective Action for the battery field incident.

- Well organized, systematical and scientific oriented root-cause Analysis
- Broad and well-designed corrective action done by Samsung& their suppliers.

by Samsung: 8-Point Battery safety Check Test ➔ one of the best Corrective Action
by IEEE: Amend IEEE1725 Standard.
by CTIA Certification: update new technology and use/environmental conditions.
by US CPSC : push all stakeholder make a battery safer.
by Harmonization with Global and National Battery safety Standard.

Root-cause analysis by Samsung and their two 3rd party parters has implied the incident cell might be changed something after the cell approval and certification.

: There is no Surveillance on CTIA Certification, but it has quality system by Manufacturing Site Audit

PCTEST Complete Wireless Lab www.pctestlab.com

Question

The cell models (company A and B) were certified from UN 38.3 Manual test, UL1624 or IEC 62133 and CTIA Battery Safety Certification under IEEE 1725.

CTIA Battery Safety Certification under IEEE 1725 has cell manufacturing site audit and product review, testing, and manufacturer self-declaration of the cell, pack, Adaptor/charger, and smartphone host system.

Why those certifications could not prevent or filter out the latent safety risky cell models?

How those certifications can be enhancing their efficiency to prevent incidents or to eliminate the cell models which containing latent safety risk in it?

There were no comments about how the defective two cell models were passed the Certification of the UN 38.3 manual test, UL 1642 / IEC 62133 and CTIA IEEE1725.

PCTEST Complete Wireless Lab www.pctestlab.com

Thank you for your Attention!!!

It is not easy to predict, prevent and completely eliminate the field incident at the point of manufacture, But it is definitely not an impossible thing.

The greatest factor is the way in which every difficulty is foreseen, victory awaits him who has everything in order luck, People said it.; Amundsen

Contact information: jaesik.chung@pctest.com