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Docket Number:	24-OPT-05
Project Title:	Corby Battery Energy Storage System Project
TN #:	268368
Document Title:	Project Description Update #2, Part 1, Appendix 2-C
Description:	Fire and Safety Reports for DC LINK Batteries
Filer:	Doug Urry
Organization:	Tetra Tech
Submitter Role:	Applicant Consultant
Submission Date:	1/30/2026 8:19:50 AM
Docketed Date:	1/30/2026

Project Description Update #2

Appendix 2-C, Fire and Safety Reports

Corby Battery Energy Storage System Project

January 2026

Prepared for

NextEra Energy Resources
700 Universe Boulevard
Juno Beach, FL 33408

Prepared by

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17885 Von Karman Avenue
Suite 500
Irvine, CA 92614

APPENDIX 2-C: FIRE AND SAFETY REPORTS FOR DC LINK BATTERIES

Appendix 2-C: Fire and Safety Reports for DC LINK Batteries

- *UL9540*
    - F2D4-5.1US-CC15_DC LINK UL9540_V1.0
    - F2D4-5.1US-CC15_DC LINK UL9540_V2.0
    - F2X4-5.1US-CC11_Pack Test Report UN38.3_V1.0
    - F2X4-5.1US-CC12_Cell Test Report UL 9540A_V1.0
    - F2X4-5.1US-CC13_Pack Test Report UL 9540A_V1.0
    - F2X4-5.1US-CC14_Unit Test Report UL 9540A_V1.0
    - LG Energy Solution_TRF_Letter_20250605
- *UL1973*
    - [UL1973] JF2 NoA_240705
    - F2D4-5.1US-CC08_DC Rack Certificate UL 1973_V1.0 (NOA)
    - F2D4-5.1US-CC09_DC Rack Test Report UL 1973_V1.0
    - F2X4-5.1US-CC04_Cell Certificate UL 1973_V1.0
    - F2X4-5.1US-CC05_Cell Test Report UL 1973_V1.0
    - F2X4-5.1US-CC06_Pack Certificate UL 1973_V1.0 (NOA)
    - F2X4-5.1US-CC07_Pack Test Report UL 1973_V1.0
- *Fire Protection*
    - F2XX-5.1US-FS09_AC&DC LINK Fire Alarm System Drawing_V5.0
- *SDS*
    - 20250731_F2XX-5.1US-GN11_Pack Product SDS (PSDS)_V2.0
    - SDS ONLY - F2D4-5.1US-TH01_DC LINK Thermal Component Specification_V4.0

Appendix 2-C: Fire and Safety Reports for DC LINK Batteries

UL9540

- F2D4-5.1US-CC15_DC LINK UL9540_V1.0
- F2D4-5.1US-CC15_DC LINK UL9540_V2.0
- F2X4-5.1US-CC11_Pack Test Report UN38.3_V1.0
- F2X4-5.1US-CC12_Cell Test Report UL 9540A_V1.0
- F2X4-5.1US-CC13_Pack Test Report UL 9540A_V1.0
- F2X4-5.1US-CC14_Unit Test Report UL 9540A_V1.0
- LG Energy Solution_TRF_Letter_20250605

UL Solutions

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2025-02-26

Hyeon Kyu Kim
LG Energy Solution, LTD.
188, Munji-ro, Yuseong-gu
Daejeon, 34122, KR

Notice of Completion (NoC) and authorization to apply the UL Mark

Your reference:		
Our reference:	File E528302, Volume 3	Order: 15556720 Project: 4791548862

Project scope: [FTBL,E528302] Model LINK-FDMEPNCN, JF2 DC LINK SYSTEM

Dear Hyeon Kyu Kim:

We appreciate that you have a choice of certification providers and thank you for choosing UL Solutions.
We have completed the investigation under the above project and confirmed compliance of your product(s) with UL Mark requirements.

This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark at the factory location(s) identified on the Authorization Page of UL Solutions File E528302, Volume 3. You are required to send a copy of this letter to all manufacturing locations authorized under UL Solutions File E528302, Volume 3.

The Follow-Up Services Procedure covering your product(s) will typically be provided by UL Solutions within 10 business days. Any information and documentation provided to you involving the UL Mark services are provided on behalf of UL LLC or any authorized licensee. The UL Solutions certification directory is updated with active certifications shortly after projects are reviewed and completed. Please visit https://productiq.ulprospector.com/ to search for the certification.

Products that bear the UL Mark must be identical to those submitted to UL for evaluation and certification and must comply with the Follow-Up Services Procedure covering your product(s). Additional requirements related to the responsibilities of the Applicant and Manufacturer can be found under **Customer Requirements documents** at www.ul.com/fus.

A UL Solutions certification is a valuable marketing tool meaning your product or company has successfully met stringent requirements. We encourage you to use your UL Mark and certification in your marketing activities. We are happy to provide guidance on how best to promote your UL certification. Our Certification Achievement Kit demonstrates marketing and promotional concepts to help you best represent your UL certification.

UL Solutions is committed to providing you with an exceptional customer experience. You may receive an email from ULSurvey@feedback.ul.com inviting you to provide feedback. Your survey rankings and comments regarding the experience are important to us. We are always seeking ways to improve in any areas we can, and your feedback and comments are vital to this process.

If you have any questions, please contact me or any of our customer service representatives at www.ul.com/contact-us.

Sincerely,

ByungHo Lee
Senior Project Engineer
UL Solutions
Byungho.Lee@ul.com

David Piecuch
UL Mark Certification Program Manager
UL LLC
David.Piecuch@ul.com

9d1b821727e2428783a272a55226c6d5

Certificate of Compliance

Certificate Number:

UL-US-2559786-3

Report Reference:

E528302-20250226

Issue Date:

2025-06-06

Issued to:

LG Energy Solution, LTD.
188, Munji-ro, Yuseong-gu, Daejeon, 34122, KR

This certificate confirms that representative samples of:

FTBL - Energy Storage Equipment Subassemblies - DC ESS

See Addendum Page for Product Designation(s).

Have been evaluated by UL in accordance with the Standard(s) indicated on this Certificate.

ANSI/CAN/UL 9540:2025, Edition 3, Issue Date 2023-06-28, Revision Date 2025-03-07

Additional Information:
See UL Product iQ® at https://iq.ulprospector.com for additional information.

This Certificate of Compliance indicates that representative samples of the product described in the certification report have met the requirements for UL certification. It does not provide authorization to apply the UL Mark. Only the Authorization Page that references the Follow-Up Services Procedure for ongoing surveillance provides authorization to apply the UL Mark.

Only those products bearing the UL Mark should be considered as being UL Certified and covered under UL's Follow-Up Services.

Look for the UL Certification Mark on the product.

David Piecuch
UL Mark Certification Program Owner

CERTIFICATE OF COMPLIANCE

Certificate number	UL-US-2559786-3
Report reference	E528302-20250226
Date	2025-06-06

This is to certify that representative samples of the product as specified on this certificate were tested according to the current UL requirements.

Energy Storage Equipment Sub-Assemblies

Model(s): LINK-FDMEPNCN *Where M can be A, B, F, or G, EPN can be 2AR, 2BL, 2CL, 2DR, 2FL, 2JR, 2KL, or 2LL, C can be 1, N can be 1, 2, or 3.*

220020349627

中国认可
国际互认
检测
TESTING
CNAS L0095

No.: RZUN2024-5420

检 测 报 告
TEST REPORT

UN38.3

NAME OF SAMPLE: 产品名称：	Rechargeable lithium-ion battery -
CLIENT: 委托单位：	LG Energy Solution, LTD. -
CLASSIFICATION OF TEST: 检测类别：	Commission Test 委托测试

威凯检测技术有限公司
CVC Testing Technology Co., Ltd.

检 测 报 告
TEST REPORT

Name of samples: Rechargeable lithium-ion battery 样品名称: -	Type/Model: 型号规格: EP096636PFB1 96V 636,8Ah 61,13 kWh
Color : White 样品颜色: 白色	Physical shape: Prismatic 样品形状: 棱柱形
Commissioned by: LG Energy Solution, LTD. 委托单位: -	Commissioner address:188, Munji-ro, Yuseong-gu, Daejeon, 34122, Republic of Korea 委托单位地址:-
Manufacturer: LG Energy Solution, LTD. 制造商: -	Manufacturer address:188, Munji-ro, Yuseong-gu, Daejeon, 34122, Republic of Korea 制造商地址: -
Factory: NANJING ZHONGSHAN ELECTRONICS Co., Ltd. 生产厂: 南京众山电池电子有限公司	Factory address: No 18 Yihu Road, Lishui Economic Development Zone, Lishui County, Nanjing, Jiangsu Province, China 211200 生产厂地址: 江苏省南京市溧水区柘塘街道柘塘镇沂湖路 18 号南京众山电池电子有限公司
Classification of test: Commission Test 检测类别: 委托测试	Quantity of sample: 4 battery packs, 30 cells 样品数量: 4 个电池组, 30 个电芯
Tested according to: 测试标准: ST/SG/AC.10/11/Rev.8/ Section 38.3	Sample identification: 样品标识序号:b1#~b4#, c1#~c30#
Receiving date: 接样日期：2024-07-22	Means of receiving: Submitted by commissioner 接样方式：委托单位送样
Completing date: 完成日期：2024-09-04	Test item: 7 items 测试项目：7 项

Test conclusion:
检测结论:

The Rechargeable lithium-ion batteries submitted by LG Energy Solution, LTD. are tested according to Section 38.3 of the Eighth revised edition of the Manual of Tests and Criteria (ST/SG/AC.10/11/Rev.8/Section 38.3). The test items are full items. The test results comply with the relevant requirements of the standard.

由-送检的 Rechargeable lithium-ion battery，依据联合国《试验和标准手册》第八修订版第 38.3 节进行检测，试验为全项目，试验结果符合标准相关要求。

Seal of CVC
CVC 盖章
Date of issue:
签发日期: 2024-09-09

Title: Manager
批准人职务： 经理

Approved by: Zhang Siyao Reviewed by: Liu Zhen Tested by: Lin Qingyuan

批 准： Zhang siyao 审 核： Liu Zhen 检 测： Lin Qingyuan

Description and illustration of the sample:
样品说明及描述:
The sample’s status is good
样品状况良好。
The battery (EP096636PFB1) is composed of cells (JF2), and the connection mode is: 4P30S
电池组（EP096636PFB1）由电芯（JF2）组成，连接方式为：4P30S
Cell Dimensions/电芯尺寸: 17,7mm * 123,5mm * 600mm
Watt-hour rating of each battery/ 单个电池组的瓦时数: 61,13kWh

Test item 试验项目	Sample No. 样品编号	State 状态	Remark 备注
T.1~T.5	b1#~b2#	at first cycle, in fully charged states 第一个交替充电放电周期完全充电状态	-
	b3#~b4#	after 25 cycles ending in fully charged states 第 25 个交替充电放电周期完全充电状态	-
T.6	c1#~c5#	at first cycle at 50% of the design rated capacity 第一个交替充电放电周期充电到设计额定容量的 50%	-
	c6#~c10#	after 25 cycles ending at 50% of the design rated capacity 第 25 个交替充电放电周期充电到设计额定容量的 50%	
T.8	c11#~c20#	at first cycle, in fully discharged states 第一个交替充电放电周期完全放电状态	-
	c21#~c30#	after 25 cycles ending in fully discharged states 第 25 个交替充电放电周期完全放电状态	-

The test objects of T.1~T.5 are battery packs, and the sample numbers are b1#~b4#
T.1~T.5 的测试对象为电池组，样品编号为 b1#~b4#。
The test objects of T.6 and T.8 are component cells, and the sample numbers are c1#~c30#
T.6、T.8 的测试对象为组成电芯，样品编号为 c1#~c30#。

Description of the sampling procedure:
取样程序的说明:
/

Description of the deviation from the standard, if any:
试验结果不符合标准项的说明:
/

Remarks:
备注：

Throughout this report a comma is used as the decimal separator.
本报告中以逗号代替小数点。

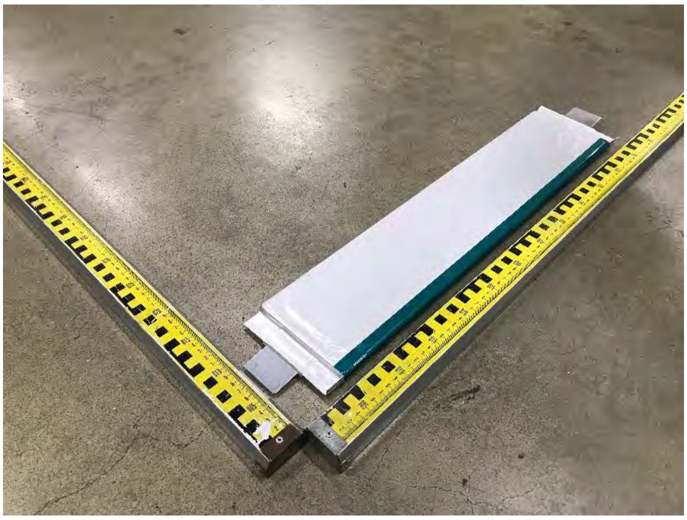
The Batteries have not equipped with overcharge protection. According to commissioner, the batteries are designed for use only in another battery, Which affords such protection, According to the UN38.3 standard, the sample is not subject to the requirements of overcharge.
该电池未安装过度充电保护装置，根据委托方声明，该样品仅设计用于另一个电池中，另一个电池上带有过度充电保护装置，根据 UN38.3 要求，无需做过度充电试验。

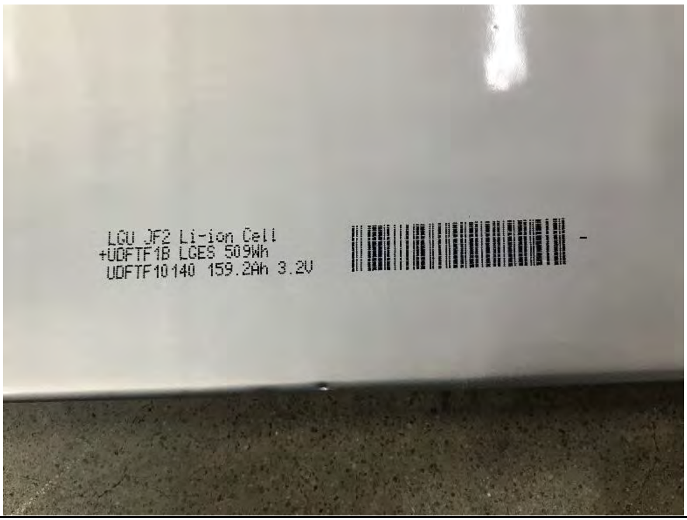
Photos of Samples and Labels/样品照片及标识

Battery/电池 （EP096636PFB1 96V 636,8Ah 61,13 kWh）

Photos of Samples and Labels/样品照片及标识

Component Cell/内部电芯（JF2 3,2V 159,2 Ah 509,44Wh ）





38.3.4	**Procedure/试验步骤**		—
	Test T.1: Altitude simulation/试验 T.1：高度模拟		
	Test cells and batteries shall be stored at a pressure of 11,6kPa or less for at least six hour at ambient temperature (20±5℃)/ 将电芯和电池在温度为 20±5℃，大气压力为不大于 11,6kpa 的环境中贮存不少于 6 个小时		
38.3.4.1	Requirement/标准要求： 1 Cells and batteries Mass loss limit: ≤0,1% /样品质量损失≤0,1% 2 Open circuit voltage not less than 90%, The requirement relating to voltage is not applicable to test cells and batteries at full discharged states. 样品试验后开路电压应不低于试验前开路电压的 90％,此要求不适用于完全放完电的电池和电芯。 3 No leakage, no venting, no disassembly, no rupture and no fire 样品（电池）应无漏液、无排气、无解体、无破裂以及无着火现象的发生	The samples b1#~b4# : No leakage, no venting, no disassembly, no rupture and no fire/编号为 b1#~b4#的样品：无漏液、无排气、无解体、无破裂以及无着火现象 The data is shown in Table 1./数据见表 1	**P**
	Test T.2: Thermal test/试验 T. 2: 温度试验		
	Test cells and batteries are to be stored for/电池存储条件如下： 1 For small cells and batteries: one temperature cycle: 72±2℃(6h) —-40±2℃(6h) /对于小型电芯和电池：一次温度循环为 72±2℃(6h) —-40±2℃(6h) For large cells and batteries: one temperature cycle: 72±2℃(12h) —-40±2℃(12h) /对于大型电芯和电池：一次温度循环为 72±2℃(12h) —-40±2℃(12h) 2 The maximum time interval between test temperature extremes is 30 minutes/温度转换最大间隔时间为 30min 3 This procedure is to be repeated 10 times/重复 10 次循环 4 after which all test cells and batteries are to be stored for 24 hours at ambient temperature (20±5℃)/循环结束后，电池在 20±5℃的条件下 搁置 24 小时		
38.3.4.2	Requirements/标准要求 1 Cells and batteries Mass loss limit: ≤0,1% /样品质量损失≤0,1% 2 Open circuit voltage not less than 90%, The requirement relating to voltage is not applicable to test cells and batteries at full discharged states. 样品试验后开路电压应不低于试验前开路电压的 90％,此要求不适用于完全放完电的电池和电芯。 3 No leakage, no venting, no disassembly, no rupture and no fire 样品（电池）应无漏液、无排气、无解体、无破裂以及无着火现象的发生	The samples b1#~b4# : No leakage, no venting, no disassembly, no rupture and no fire/编号为 b1#~b4#的样品：无漏液、无排气、无解体、无破裂以及无着火现象 The data is shown in Table 1./数据见表 1	**P**

<table>
<tr><td rowspan="3">**38.3.4.3**</td><td colspan="2">**Test T.3: Vibration/试验 T. 3: 振动**</td><td rowspan="3">**P**</td></tr>
<tr><td colspan="2">1 Cells and batteries are firmly secured to the platform of the vibration machine /电芯和电池牢固地安装在振动台（的台面）上

2 The vibration: a sinusoidal waveform with a logarithmic sweep between 7Hz and 200Hz and back to 7Hz traversed in 15 minutes/振动以正弦波形式，以 7Hz 增加至 200Hz，然后在减少回到 7Hz 为一个循环，一个循环持续 15 分钟的对数前移传送。

3 For cells and small batteries: from 7 Hz a peak acceleration of 1gn is maintained until 18Hz is reached. The amplitude is then maintained at 0,8mm (1,6mm total excursion) and the frequency increased until a peak acceleration of $8g_n$ occurs (approximately 50Hz). A peak acceleration of $8g_n$ is then maintained until the frequency is increased to 200Hz. / 对于电芯和小型电池：从 7Hz 开始，以 $1g_n$ 的峰值加速度保持不变，直到达到 18Hz。然后将振幅保持在 0,8mm（总偏移 1,6mm）并且频率增加直到出现 $8g_n$ 的峰值加速度（大约 50Hz）。然后保持 $8g_n$ 的峰值加速度，直到频率增加到 200Hz。

For large batteries: from 7Hz a peak acceleration of $1g_n$ is maintained until 18Hz is reached. The amplitude is then maintained at 0,8mm (1,6mm total excursion) and the frequency increased until a peak acceleration of $2g_n$ occurs (approximately 25Hz). A peak acceleration of $2g_n$ is then maintained until the frequency is increased to 200Hz. / 对于大型电池：从 7Hz 开始，以 $1g_n$ 的峰值加速度保持不变，直到达到 18Hz。然后将振幅保持在 0,8mm（总偏移 1,6mm）并且频率增加直到出现 $2g_n$ 的峰值加速度（大约 25Hz）。然后保持 $2g_n$ 的峰值加速度，直到频率增加到 200Hz。

4 This cycle repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting position of the cell. One of the directions of vibration must be perpendicular to the terminal face. /以振动的其中一个方向必须是垂直样品极性，对每个电芯从三个互相垂直的方向上循环 12 次，每个方向 3 个小时，共 9 小时。</td></tr>
<tr><td>Requirements/标准要求

1 Cells and batteries Mass loss limit: ≤0,1% /样品质量损失≤0,1%

2 Open circuit voltage not less than 90%, The requirement relating to voltage is not applicable to test cells and batteries at full discharged states.
样品试验后开路电压应不低于试验前开路电压的 90％,此要求不适用于完全放完电的电池和电芯。
3 No leakage, no venting, no disassembly, no rupture and no fire
样品（电池）应无漏液、无排气、无解体、无破裂以及无着火现象的发生</td><td>The samples b1#~b4#:

No leakage, no venting, no disassembly, no rupture and no fire/编号为 b1#~b4#的样品：无漏液、无排气、无解体、无破裂以及无着火现象

The data is shown in Table 1./数据见表 1</td></tr>
</table>

<table>
<tr><td rowspan="3">38.3.4.4</td><td colspan="2">Test T.4: Shock/试验 T. 4: 冲击</td><td rowspan="3">P</td></tr>
<tr><td colspan="2">1 Test cells and batteries shall be secured to the testing machine/以稳固的托架固定住每个电芯和电池样品的全部配件表面。
2 Each cell shall be subjected to a half-sine shock of peak acceleration of 150 g_n and pulse duration of 6 milliseconds. Large cells may be subjected to a half-sine shock of peak acceleration of 50 gn and pulse duration of 11 milliseconds. / 对每个电芯以峰值为 150g_n 的半正弦的加速度撞击，脉冲持续 6 毫秒，大型电芯须经受最大加速度 50g_n 和脉冲持续时间 11 毫秒的半正弦波冲击。
Small batteries shall be subjected to a half-sine shock of peak acceleration of 150 g_n (or Acceleration(g_n)= $\sqrt{\left(\frac{100850}{mass}\right)}$, which is smaller) and pulse duration of 6 milliseconds, large batteries shall be subjected to a half-sine of peak acceleration of 50 g_n (or Acceleration(g_n)= $\sqrt{\left(\frac{30000}{mass}\right)}$, which is smaller) and pulse duration of 11 milliseconds/对每个电池以峰值为 150g_n（或与 $\sqrt{\left(\frac{100850}{mass}\right)}$ 中的较小值）的半正弦的加速度撞击，脉冲持续 6 毫秒，大型电池须经受最大加速度 50g_n（或与 $\sqrt{\left(\frac{30000}{mass}\right)}$ 中的较小值）和脉冲持续时间 11 毫秒的半正弦波冲击。
3 Each cell or battery shall be subjected to three shocks in the positive direction followed by three shocks in the negative direction of three mutually perpendicular mounting positions of the cell or battery for a total of 18 shocks/每个电池或电池组须在三个互相垂直的电池安装方位的正方向经受三次冲击，接着在反方向经受三次冲击，总共经受 18 次冲击。</td></tr>
<tr><td>Requirements/标准要求：
1 Cells and batteries Mass loss limit: ≤0,1% /样品质量损失≤0,1%
2 Open circuit voltage not less than 90%, The requirement relating to voltage is not applicable to test cells and batteries at full discharged states.
样品试验后开路电压应不低于试验前开路电压的 90％,此要求不适用于完全放完电的电池和电芯。
3 No leakage, no venting, no disassembly, no rupture and no fire
样品（电池）应无漏液、无排气、无解体、无破裂以及无着火现象的发生</td><td>The samples b1#~b4# ：
Acceleration= 8.6g_n
No leakage, no venting, no disassembly, no rupture and no fire/编号为 b1#~b4#的样品：
峰值加速度= 8.6g_n
无漏液、无排气、无解体、无破裂以及无着火现象
The data is shown in Table 1./数据见表 1</td></tr>
</table>

38.3.4.5	**Test T.5: External Short Circuit/试验 T.5 外部短路**		**P**
	1The cell or battery to be tested shall be temperature stabilized so that its external case temperature reaches 57±4℃/保持试验环境温度稳定在 57±4℃，以使电芯或电池样品外表温度达到 57±4℃ 2 the cell or battery shall be subjected to a short circuit condition with a total external resistance of less than 0,1 ohm at 57±4℃, This short circuit condition is continued for at least one hour after the cell or battery external case temperature has returned to 57±4℃, or in the case of the large batteries, has decreased by half of the maximum temperature increase observed during the test and remains below that value. /将样品正负极用小于 0,1Ω 的总电阻回路进行短路，样品的外表温度恢复到 57±4℃之后保持短路状态 1 小时以上；对于大电池，电池温度降低至最高温升值的一半时实验结束。 3 the cell or battery must be observed for a further six hour for the test to be concluded, /对电芯或电池必须进一步观察 6 个小时才能下结论。		
	Requirements/标准要求： During the test and within six hours after test ,the cells or batteries 在试验过程中以及之后 6 个小时内，电芯或电池样品 1. External temperature not exceed 170℃ 外表温度不超过 170℃ 2. No disassembly, no rupture and no fire. 无解体、无破裂和无着火现象发生。	The samples b1#~b4# ： no disassembly, no rupture and no fire/编号为 b1#~b4# 的样品：无解体、无破裂以及无着火现象 The data is shown in Table 1./数据见表 1	

	Test T.6: Impact / Crush / 试验 T.6: 撞击/挤压		**P**
	Impact (applicable to cylindrical cells not less than 18mm in diameter) / 撞击（适用于直径不小于 18 毫米的圆柱形电池）		**N/A**
	1 This test sample cell or component cell is to be placed on a flat smooth surface/ 将试验样品用的电芯或聚合物电芯放在一个平坦光滑的平面上 2 A 15,8 mm diameter bar is to be placed across the centre of the sample, A 9,1kg mass is to be dropped from a height of 61±2,5cm onto the sample./将一直径为 15,8mm 的不锈钢圆棒横过电池中部放置后，将一质量为 9,1kg 的物体从 61±2,5cm 的高度落向样品。 3 The test sample is to be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the 15,8 mm ± 0,1mm diameter curved surface lying across the centre of the test sample. Each sample is to be subjected to only a single impact./ 接受撞击的试样，纵轴应与平坦的表面平行并与横放在试样中心的直径 15,8±0,1 毫米弯曲表面的纵轴垂直。每一个试样只经受一次撞击。		
	Requirements/标准要求： 1 Cells external temperature not exceed 170℃.电芯或电池的最高表面温度应不超过 170℃ 2 No disassembly, no fire within six hours of this test 试验结束后 6 个小时之内，电芯和聚合物电芯应无解体和无着火现象发生	-	
38.3.4.6	Crush (applicable to prismatic, pouch, coin/button cells and cylindrical cells less than 18mm in diameter) / 挤压（适用于棱柱形、袋装、硬币/纽扣电池和直径小于 18 毫米的圆柱形电池）		**P**
	1 A cell or component cell is to be crushed between two flat surfaces. The crushing is to be gradual with a speed of approximately 1,5 cm/s at the first point of contact. The crushing is to be continued until the first of the three options below is reached. / 将电池或元件电池放在两个平面之间挤压，挤压力度逐渐加大，在第一个接触点上的速度大约为 1,5 厘米/秒。挤压持续进行，直到出现以下三种情况之一： (a) The applied force reaches 13 kN ± 0,78 kN. / 施加的力达到 13 千牛±0,78 千牛 (b) The voltage of the cell drops by at least 100 mV,/电池的电压下降至少 100 毫伏 (c) The cell is deformed by 50% or more of its original thickness./电池变形达原始厚度的 50%以上。 2. A prismatic or pouch cell shall be crushed by applying the force to the widest side. A button/coin cell shall be crushed by applying the force on its flat surfaces. For cylindrical cells, the crush force shall be applied perpendicular to the longitudinal axis. /棱柱形或袋装电池应从最宽的一面施压。纽扣/硬币形电池应从其平坦表面施压。圆柱形应从与纵轴垂直的方向施压。		
	Requirements/标准要求： 1 Cells external temperature not exceed 170℃.电芯或电池的最高表面温度应不超过 170℃ 2 No disassembly, no fire within six hours of this test 试验结束后 6 个小时之内，电芯和聚合物电芯应无解体和无着火现象发生	The samples c1#~c10#: no disassembly and no fire/ 编号为 c1#~c10#的样品：无解体、无着火现象 The data is shown in Table 2./数据见表 2	

38.3.4.7	**Test T.7: Overcharge/试验 T. 7: 过度充电**		N/A
	1 The charge current shall be twice the manufacturer’s recommended maximum continuous charge current/以 2 倍制造厂推荐的最大持续充电电流对样品充电 2 The minimum voltage of the test shall be as follows/本试验最小电压为:		
	a) When the manufacturer’s recommended charge voltage is not more than 18V, the minimum voltage of the test shall be the lesser of two times the maximum charge voltage of the battery or 22V/ 如果厂家推荐的充电电压不超过 18V，本试验的最小充电电压应是厂家标定最大充电电压的两倍或者是 22V 之中的较小者。 b) When the manufacturer’s recommended charge voltage is more than 18V, the minimum voltage of the test shall be 1,2 times the maximum charge voltage/ 如果厂家推荐的充电电压超过 18V，本试验的最小充电电压应是厂家标定最大充电电压的 1,2 倍。 3 Tests are to be conducted at ambient temperature 20±5℃, The duration of the test shall be 24 hours/20±5℃的环境温度下，试验持续 24 小时。	-	
	Requirements/标准要求: No disassembly and no fire within seven days of this test 试验样品在试验中和试验后 7 天内，应无解体和无着火现象发生。	-	
38.3.4.8	**Test T.8: Forced discharge/试验 T. 8: 强制放电**		P
	Each cell shall be forced discharged at ambient temperature by connecting it in series with a 12 V D.C. power supply at an initial current equal to the maximum discharge current specified by the manufacturer, 20±5℃的环境温度下，将单个电芯连接在 12V 的直流电源上进行强制放电，此直流电源提供给每个电芯初始电流为制造厂指定的最大放电电流。		
	The specified discharge current is to be obtained by connecting a resistive load of the appropriate size and rating in series with the test cell. Each cell shall be forced discharged for a time interval (in hours) equal to its rated capacity divided by the initial test current (in ampere) 指定的放电电流通过串联在试验电芯上的合适大小和功率的负载来获得，每个电芯的强制放电时间（小时）为额定容量除以初始电流（安培）。		
	Requirements/标准要求: No disassembly and no fire within seven days of this test 试验样品在试验中和试验后 7 天内，应无解体和无着火现象发生。	The samples c11#~c30#: no disassembly and no fire/编号为 c11#~c30#的样品：无解体、无着火现象 The data is shown in Table 3./数据见表 3	

Table1：T1~T5 / 表 1. 试验 1~试验 5

Sample No. 样品号	**Mass prior to test / 试验前质量 (kg)**	**OCV prior to test /试验前电压(V)**	**Test T.1: Altitude simulation/ 试验 T.1：高度模拟**		**Test T.2: Thermal test/ 试验 T.2: 温度试验**		**Test T.3: Vibration/ 试验 T.3: 振动**		**Test T.4: Shock/ 试验 T.4: 冲击**		**Test T.5: External Short Circuit/试验 T.5 外部短路**
			Mass Loss(%) 质量损失(%)	OCV Retention Ratio(%) 电压保留比(%)	Mass Loss(%) 质量损失(%)	OCV Retention Ratio(%) 电压保留比(%)	Mass Loss(%) 质量损失(%)	OCV Retention Ratio(%) 电压保留比(%)	Mass Loss(%) 质量损失(%)	OCV Retention Ratio(%) 电压保留比(%)	Temp. (℃) 温度 (℃)
b1#	405,500	100,200	0,000	100,00	0,000	100,00	0,000	100,00	0,000	100,00	57,1
b2#	409,500	100,300	0,000	100,00	0,000	99,70	0,000	100,00	0,000	99,90	57,2
b3#	402,500	100,300	0,000	100,00	0,000	99,80	0,000	99,80	0,000	100,00	57,1
b4#	405,500	100,200	0,000	100,00	0,000	99,90	0,000	99,90	0,000	99,90	57,4

Table2: Crush /表 2:挤压

Test T.6: Crush/试验 T.6:挤压	Sample No. 样品号	c1#	c2#	c3#	c4#	c5#	c6#	c7#	c8#	c9#	c10#
	OCV prior to test / 试验前电压（V）	3,301	3,301	3,301	3,301	3,301	3,302	3,301	3,302	3,301	3,301
	Temp. (℃) 温度 (℃)	25,2	25,4	25,5	25,1	25,2	25,3	25,3	25,2	25,1	25,2

Table 3：Forced discharge / 表 3. 强制放电

Test T.8: Forced discharge **/ 试验 T.8:** 强制放电	Sample No. 样品号	c11#	c12#	c13#	c14#	c15#	c16#	c17#	c18#	c19#	c20#
	OCV prior to test / 试验前电压(V)	3,009	3,009	3,009	3,009	3,009	3,009	3,009	3,009	3,009	3,009
	Sample No. 样品号	c21#	c22#	c23#	c24#	c25#	c26#	c27#	c28#	c29#	c30#
	OCV prior to test / 试验前电压(V)	3,009	3,009	3,009	3,009	3,009	3,009	3,009	3,009	3,009	3,009

注 意 事 项
Important

1. 报告无检测单位印章无效。
   The test report is invalid without the seal of CVC.
2. 未经本试验室书面同意，不得部分地复制本报告。
   Nobody is allowed to photocopy or partly photocopy this test report without written permission of CVC.
3. 本报告无批准人、审核人及检测人签名无效。
   The test report is invalid without the signatures of Ratifier, Reviewer and Testing engineer.
4. 本报告涂改无效。
   The test report is invalid if altered,
5. 对检测报告若有异议，应于收到报告之日起十五天内向检测单位提出。
   Objections to the test report must be submitted to CVC within 15 days.
6. 本报告仅对送检样品负责。
   The test report is valid for the tested samples only.
7. 判定栏中"-"表示"不需要判定"，"P"表示"通过"，"F"表示"不通过"，"N/A"表示"不适用"。
   As for the Verdict, "-" means "no need for judgement", "P" means "pass"， "F" means "fail" and "N/A" means "not applicable".

报告中未加CMA 标志时，检测数据和结果仅供科研、教学或内部质量控制之用。
The test data and test results given in this test report should only be used for purposes of scientific research, teaching and internal quality control when the CMA symbol is not presented.

地 址： 广东省广州市科学城开泰大道天泰一路 3 号
广东省广州市黄埔区光谱东路 179 号百事高智慧园 D 栋（测试地点）
Lab Address: No.3, Tiantai 1st Road, Kaitai Avenue, Science City, Guangzhou， Guangdong, China.
Testing Location: Building D, BASIGO INTELLIGENT, No.179, Guangpu East Road, Huangpu District, Guangzhou, P. R. China.
电 话(Tel)：020 32293888 邮政编码(Post Code)：510663
传 真(FAX)：020 32293889 E-mail： office@cvc.org.cn
http://www.cvc.org.cn

UN38.3 Lithium Battery (Cell) Test Summary
UN38.3 锂电池(电芯)试验概要

No. : RZUN2024-5420-TS

Cell or Battery Information 电池/电芯信息		
Name 名称:	Rechargeable lithium-ion battery	Other Physical Description: 其它相关描述: —
Type/Model 型号规格:	EP096636PFB1 96V 636.8Ah 61.13 kWh	
Color 颜色:	White / 白色	
Shape 形状:	Prismatic/棱柱形	
Completed Battery/Cell Mass 电池/电芯整体质量	402.500kg ~ 409.500kg	
☒ Belongs to Lithium-ion Battery/Cell, the Wh rating is 属于锂离子电池/电芯，瓦时数为	61.13kWh	
☐ Belongs to Lithium metal Battery/Cell, the Lithium content is 属于锂金属电池/电芯，锂金属含量为		

Manufacturer Information 制造商信息			
Manufacturer： 制造商：	LG Energy Solution, LTD.		
Address: 地址:	188, Munji-ro, Yuseong-gu, Daejeon, 34122, Republic of Korea		
Telephone 电话:	+82-10-8215-8219	Email 电邮:	doheo@lgensol.com
Website 网址:	www.lgensol.com		

Laboratory Information 检测试验室信息					
Laboratory: 检测试验室:	CVC Testing Technology Co., Ltd. 威凯检测技术有限公司				
Address: 地址:	No.3, Tiantai 1st Road, Kaitai Avenue, Science City, Guangzhou， Guangdong, China. Building D, BASIGO INTELLIGENT, No.179, Guangpu East Road, Huangpu District, Guangzhou, P. R. China. 广东省广州市科学城开泰大道天泰一路 3 号 广东省广州市黄埔区光谱东路 179 号百事高智慧园 D 栋				
Tel 电话:	+86-20-32293888	Email 电邮:	office@cvc.org.cn	Website 网址:	http://www.cvc.org.cn

UN38.3 Test conducted and results UN38.3 试验项目和结果			
Test Report ID 检测报告编号：	RZUN2024-5420	Date of Test Report 检测报告签发日期：	2024-09-09
Manual of Test and Criteria version / amendment：试验和标准手册版本号/修订版：		ST/SG/AC.10/11/Rev.8/Section 38.3	

List of Tests Completed 已完成的试验项目清单

Test Items 试验项目	Pass 通过	Fail 失败	Reference to assembled battery testing requirement: 关于组合电池的试验要求:
☒ T.1 Altitude Simulation 高度模拟	☒	☐	☒ Not applicable 不适用
☒ T.2 Thermal Test 温度试验	☒	☐	
☒ T.3 Vibration 振动	☒	☐	☐ Applicable，reference to 38.3.3 (f) 适用于 38.3.3 (f)
☒ T.4 Shock 冲击	☒	☐	
☒ T.5 External Short Circuit 外部短路	☒	☐	☐ Applicable，reference to 38.3.3 (g) 适用于 38.3.3 (g)
☒ T.6 Impact/ Crush 撞击/ 挤压	☒	☐	
☐ T.7 Overcharge 过度充电	☐	☐	Other executive standards/其他执行标准:
☒ T.8 Forced Discharge 强制放电	☒	☐	

Note：The test results of this summary are only valid for the tested samples listed in test report RZUN2024-5420.

注：此摘要的测试结果仅对测试报告 RZUN2024-5420 中列出的测试样品有效

Title/职务: Manager/经理

Seal of CVC
CVC 盖章

Signatory/签发人: 张思瑶 (张思瑶)

中国认可
检验
INSPECTION
CNAS IB0011

运输危险性鉴定报告书

Classification and Identification Report for Transport

No.: UN2024-5420-1

海运 By Sea	第九类危险品（LP903） Dangerous Goods Class 9 (LP903) 报告有效期 Period of validity：2024-12-31

样 品 名 称 ....: -

EP096636PFB1 96V 636,8Ah 61,13 kWh

Sample Name............ : **Rechargeable lithium-ion battery**

EP096636PFB1 96V 636,8Ah 61,13 kWh

委 托 单 位 ....: -

Commissioner .... : **LG Energy Solution, LTD.**

威凯检测技术有限公司

CVC Testing Technology Co., Ltd.

运输危险性鉴定报告书

Classification and Identification Report for Transport

样品信息/ Sample information	
样品名称 ....:	-
Sample name.............................:	Rechargeable lithium-ion battery
电池类别/Battery Category ....:	锂离子电池/Lithium-ion batteries
电池型号规格/Battery Type........:	EP096636PFB1 96V 636,8Ah 61,13 kWh
外观颜色/ Appearance............ :	白色 / White
委托单位/ Commissioner information	
委托单位 ....:	-
Commissioned by ....:	LG Energy Solution, LTD.
制造商/Manufacturer information	
制造商 ....:	-
Manufacturer ....:	LG Energy Solution, LTD.
包装件信息/Package information	
包装件重量/Package weight ......:	466,5 kg
电池净重/ Battery net weight .....:	410 kg
电池个数/ Battery Number.........:	1 pc
包装件尺寸/Package size ....:	2200mm * 1030mm * 460mm
时间信息/ Date	
鉴定日期/ Inspection date.......... :	2024-07-22 ~ 2024-09-04
报告有效期/ Period of validity .... :	2024-12-31

鉴定依据/Inspection refer to..

国际海事组织《国际海运危险货物规则》（2022 版）

IMO INTERNATIONAL MARITIME DANGEROUS GOODS CODE (2022 Edition)

鉴定结论/ Conclusions

1. 运输名称/Proper Shipping name:

— Lithium ion batteries

2. 危险性识别/ Hazards identification ：

— 第九类 UN3480/ Class 9 UN3480

3. 包装符合 IMDG CODE（Amdt. 41-22）2022 版包装导则 LP903 的要求/ Package complies with the Packing Instruction LP903 of IMDG CODE（Amdt. 41-22）2022 Edition.

— 包装件满足包装等级 II 的要求。/ The package meet the Packing Group II performance standards.

签发日期：
Issue Date: 2024-09-09

鉴定单位盖章
(Seal of CVC)

批准:	张思瑶	审核:	柳震	检验:	林清源
Approved by:	张思瑶	Reviewed by:	柳震	Inspected by:	林清源

检验结果及其他事项 Inspection results and other information	
1	本报告所述锂电池已经通过联合国《试验和标准手册》第三部分第 38.3 节的相关测试要求。UN38.3 测试报告编号及试验概要的编号为：RZUN2024-5420 / RZUN2024-5420-TS。 The Lithium cells/batteries listed in the report are of type proven to meet the requirements of each test in the UN Manual of Tests and Criteria Part III subsection 38.3. The UN38.3 test report and test summary numbers are RZUN2024-5420 / RZUN2024-5420-TS.
2	本报告所述锂电池按照《国际海运危险货物规则》（41-22）2022 版 2.9.4（5）规定的质量管理体系进行制造。 Lithium cells and batteries listed in this report were manufactured under the quality management program as described in IMDG CODE (Amdt. 41-22) 2022 Edition 2.9.4 (5).
3	本报告所述锂电池具有适当的防短路措施。 Lithium cells and batteries listed in this report are properly protected so as to prevent short circuits.
4	本报告所述锂电池装在能完全封闭其的内包装再放置在坚固外包装。 Lithium cells and batteries listed in this report are packed in inner packagings that completely enclose the cell or battery then place in a strong outer package.

备注：
Remarks:

该报告中逗号用以代替小数点。
Throughout this report a comma is used as the decimal separator.

样品照片
Photos of Samples

电池/ Battery(EP096636PFB1 96V 636,8Ah 61,13 kWh)

包装照片
Photos of Packages

包装件/ Package

注 意 事 项

Important Notice

1. 本鉴定报告书仅对送检样品有效。
   This report is valid for the tested samples only.
2. 申请人提供的样品须与实际运输货物一致。
   The goods applied for shipment must be in conformity with the tested samples.
3. 本鉴定报告书无鉴定单位印章无效。
   This report is invalid without the seal of CVC.
4. 本鉴定报告书无批准人、审核人及检验人签名无效。
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   This appraisal report can be verified by scanning the QR code on the cover or on the website http://www.cvc.org.cn.

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http://www.cvc.org.cn

CELL TEST REPORT
UL 9540A
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)

Project Number................................:	**4791256609**
Date of issue ....:	**2024-10-09**
Total number of pages...................:	**39**
UL Report Office ....:	**UL Solutions Korea**
Applicant's name............................:	**LG ENERGY SOLUTION, LTD.**
Address ....:	188, MUNJI-RO, YUSEONG-GU DAEJEON, 34122 REPUBLIC OF KOREA
Test specification:	4th Edition, Section 7, November 12, 2019
Standard ....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure ....:	7.1, 7.2, 7.3.1, 7.4, 7.6.1, 7.7
Non-standard test method ....:	N/A

General disclaimer:

The test results presented in this report relate only to the sample tested in the test configuration noted on the list of the attachments.

UL Solutions did not select the sample(s), determine whether the sample(s) was representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation or identification of component materials used in the test sample(s).

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Cell level information	
Model No ....:	JF2
Ratings (Vdc, Ah) ....:	3.2 Vdc, 159.2 Ah
Chemistry of test item………………:	LiFePO4+C6 ⇔ LiC6+FePO4
Original Equipment Manufacturer (OEM):	LG ENERGY SOLUTION, LTD.
Branding Manufacturer (if not OEM):	N/A
Was the cell certified? …………………………:	Yes
Standard test item certified to …………..:	UL 1973 Annex E
Organization that certified test item …….:	UL Solutions (File Number : MH63736)
Average cell surface temperature at gas venting, °C:	128.9
Average surface temperature at thermal runaway, °C:	209.6
Gas Volume:	64.0
Lower flammability limit (LFL), % volume in air at the ambient temperature	7.4
Lower flammability limit (LFL), % volume in air at the venting temperature	6.6
Burning velocity (S_u) cm/s:	85.6
Maximum pressure (P_{max}) psig:	98.9

Cell Gas composition

Gas	Measured %
Hydrogen	59.3%
Carbon monoxide	10.0%
Carbon dioxide	22.4%
Methane	3.68%
Ethane	0.53%
Ethylene	2.53%
Acetylene	0.16%
Propane	0.12%
Propene (Propylene)	0.26%
C4 Total	0.40%
C5 Total	0.12%
C6 Total	0.39%
C7 Total	0.04%
C8 Total	0.06%
Benzene	0.09%
Toluene	0.01%
Xylene	0.01%
Total	**100%**

Cell failure test method performed (summary of method and test clause):

☒ External heating using thin film with 4°C to 7°C thermal ramp.
☐ Nail Penetration
☐ Overcharge
☐ External short circuit (***X*** Ω *external resistance*)
☐ Flow Battery with 2 active electrolyte methods
☐ Flow Battery with 1 active electrolyte methods
☐ Others

Description of method used to fail cells if other than external thin film heater with thermal ramp, :
N/A

Summary of testing:

Performance Criteria in accordance with Clause 7.7 and Figure 1.1:

[ ] Thermal runaway was not induced in the cell; and

[ ] The cell vent gas did not present a flammability hazard when mixed with any volume of air, as determined in accordance with ASTM E918 at both ambient and vent temperatures.

Necessity for a module level test

[X] The performance criteria of the cell level test as indicated in 7.7 of UL 9540A 4th edition has not been met, therefore a module level testing in accordance with UL 9540A will need to be conducted on a complete module employing this cell.

[ ] The performance criteria of the module level tests as indicated in 7.7 of UL 9540A 4th edition has been met, therefore a module level testing in accordance with UL 9540A need not be conducted.

Testing Laboratory information		
Testing Laboratory and testing location(s):		
Testing Laboratory:	UL Solutions	
Testing location/ address .... :	333 Pfingsten Rd. Northbrook, Il 606626 USA	
Tested by (name, signature)........................ :	Miguel Berumen	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) .... :	--	--
Project Handler (name, signature).............. :	Leon Lee	Leon Lee
Reviewer (name, signature) …………….:	Nicholas Voss	Nicholas Voss
Gas Analysis Testing Laboratory:		
Testing location/ address .... :	UL Solutions 333 Pfingsten Rd. Northbrook, Il 606626 USA	
Project Handler (name, signature)............. :	Anirudh Lakshmi Narasimhan	
Reviewer (name, signature) …………….:	Nicholas Voss	
List of Attachments (including a total number of pages in each attachment):		

Attachment A: Cell Conditioning (Charge/discharge) Profiles - (*Pages **17** through **21***)
Attachment B: Cell Instrumentation Photos - (*Pages **22** through **27***)
Attachment C: Cell Temperature Profiles during testing - (*Pages **28** through **30***)
Attachment D: Cell Testing Photos - (*Pages **31** through **35***)
Attachment E: Cell Test Datasheets - (*Pages **36** through **36***)
Attachment F: Cell vent gas test chamber photo and profile of chamber gas analysis (O_2 and Pressure) - (*Pages **37** through **38***)
Attachment G: Certification Requirement Decision - (*Pages **39** through **39***)

Photo of cell/Stack:

Test Item Charge/Discharge Specifications:[1]	
• **Charge current, A:**	**39.8**
• **Standard full charge voltage, Vdc:**	**3.65**
• **Charge temperature range, °C:**	**0 to 45**
• **End of charge current, A:**	**7.96**
• **Discharge current, A:**	**39.8**
• **End of discharge voltage, Vdc:**	**2.5**
• **Discharge temperature range, °C:**	**0 to 45**

[1] Cell samples were conditioned by charging them to the standard full voltage of 3.65V and then discharging them to the end of discharge voltage of 2.5V as specified by the manufacturer. Although the cells for top off were charged to 4.1V, standard full charge voltage was considered to be 3.65V and the end of discharge voltage was considered to be 2.5V.

Test item particulars	
Possible test case verdicts:	
- test case does not apply to the test object...........:	N/A
- test object does meet the requirement ....:	P (Pass)
- test object does not meet the requirement...........:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Testing	
Date of receipt of test item ....:	2024-05-10
Date (s) of performance of tests ....:	2024-06-18 to 2024-07-03
General remarks:	
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report. **Throughout this report a point is used as the decimal separator.**	
Manufacturer's Declaration of samples submitted for test:	
The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided ....:	☒ **Yes** ☐ **Not applicable**
Name and address of factory (ies) .... :	1. LG ENERGY SOLUTION, LTD. OCHANG PLANT 29, GWAHAKSANEOP 3-RO, OKSAN-MYEON, HEUNGDEOK-GU, CHEONGJU-SI, CHUNGCHEONGBUK-DO, 28122, REPUBLIC OF KOREA 2. LG ENERGY SOLUTION TECHNOLOGY (NANJING) CO., LTD. NO 16 HONGLI ROAD, JIANGNING STREET, NANJING, JIANGSU, 211100, CHINA The samples submitted for evaluation were manufactured in factory No.1, OCHANG PLANT.
General product information and other remarks:	
JF2 is a rechargeable li-ion battery cell manufactured by LG ENERGY SOLUTION, LTD.. The cell is rated for 3.2 Vdc, 159.2 Ah. See table Critical components information for details.	

UL 9540A, Edition 4			
Clause	Requirement + Test	Result - Remark	Verdict
5.0	**CONSTRUCTION**		
5.1. 5.4	**Cell/Stack Construction**		—
5.1.1, 5.4.1	Generic Chemistry:	LiFePO4+C6 ⇔ LiC6+FePO4	—
	Electrolyte Chemistry:	LiPF6 salt + EC/EMC/DMC solvent	—
	Flow Battery Electrolyte No. 1 Chemistry:	N/A	—
	Max volume of system electrolyte No. 1, L:	N/A	—
	Flow Battery Electrolyte No. 2 Chemistry:	N/A	—
	Max volume of system electrolyte No. 2, L:	N/A	—
	Separator Melt Temperature, °C:		—
	Format: Cylindrical /Prismatic /Pouch Flow Battery Stack	Pouch	—
	Overall Dimensions, mm	125 mm by 601 mm by 18 mm (Max.)	—
	Cell Weight, g	(Max.) 2800g	—
5.1.2	Cell Certification:	Certified	—
	Standard Used for Cell Certification:	UL1973 (File Number : MH63736)	—
	Organization that Certified Cell:	UL Solutions	—
5.1.1, 5.4.1	Cell/Stack Ratings: • Nominal Voltage, Vdc •Nominal Capacity, Ah	3.2 Vdc 159.2 Ah	— —
5.4.1	Flow Battery: No. of Cells per Stack:	N/A	—
	Flow battery system manufacturer:	N/A	—
	Flow battery system model:	N/A	—
	Flow battery system ratings, Vdc, Ah:	N/A	—
5.4.2	Flow battery system certified to UL 1973:	N/A	—
	Organization that certified flow battery system:	N/A	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		
7.2	**Samples**		

UL 9540A, Edition 4			
Clause	Requirement + Test	Result - Remark	Verdict
7.2.1	Samples conditioned through charge discharge cycling a minimum of 2 cycles.	See Attachment A for profiles See Table 1 for specifications	C
7.2.2	100% SOC and stabilize from 1h to 8 h before testing		
7.2.3	Pouch Cells constrained per end use during testing.	--	C
7.3	**Determination of thermal runaway methodology**		
7.3.1	**General**		
7.3.1.1	Ambient indoor laboratory conditions: 25 ±5°C (77 ±9°F) ≤50 ±25% RH at the initiation of the test.	See Attachment Table 3 Ambient indoor laboratory conditions are between 23.0 and 27.5℃	C
7.3.1.2	Heat the cell to thermal runaway by externally applied flexible film heaters	See Attachment B	C
	Heater Dimension	Width 540 mm by Height 90 mm	
	A surface heating rate of 4° C (7.2° F) to 7° C (12.6° F) per minute was applied to the cell.	See Table 4.	C
	Maximum surface end point temperature, °C	In accordance with Certification Requirement Decision dated on 2020-05-20, no holding temperature used for the test. Please refer to Attachment G.	
	The following method(s) was employed to cause thermal runaway: ☐ Mechanical (e.g. nail penetration); ☐ Electrical stress in the form of overcharging, ☐ Electrical stress in the form of over discharging ☐ Electrical stress in the form of external short-circuiting ☐ Use of alternate heating sources (e.g. oven). ☐ Other (explain)	External heater applied	N/A
7.3.1.3	Detail of test method when using another cell abuse method to initiate thermal runaway	--	N/A
7.3.1.4	Monobloc batteries such as a lead acid battery	--	N/A
7.3.1.5	Estimated surface temperature at which internal short circuiting within the cell will occur that could lead to a thermal runaway condition.	--	N/A
7.3.1.6	The cell was heated until thermal runaway has occurred.	Refer to Attachment C and D	C

UL 9540A, Edition 4			
Clause	Requirement + Test	Result - Remark	Verdict
	Another external heating method was used to cause cell thermal runaway	--	N/A
7.3.1.7	The cell's exterior surface temperature was measured	See Attachment B	C
7.3.1.8	The temperature at which the cell case vents due to internal pressure rise was documented.	See Table 4 See Attachment Cand D	C
7.3.1.9	The temperature at the onset of thermal runaway was documented.	See Table 4 See Attachment Cand D	C
	If cell venting occurs first, the cell was heated continuously until thermal runaway occurs.	See Attachment C	C
7.3.1.10	When using methods other than the heater method, the stresses were applied to the cell until thermal runaway occurs.	--	N/A
7.3.1.11	3 additional samples were tested using the same method and exhibited thermal runaway	See Table 3, 4 and 5 See Attachment Cand D	C
7.4	**Cell vent gas composition test**		
7.4.1	Cell vent gas was generated and captured by forcing a cell into thermal runaway with the methodology developed in 7.3, inside a pressure vessel	Size of pressure vessel used: 82L Refer to Attachment F	C
	The test was initiated with an initial condition of atmospheric pressure and less than 1% oxygen by volume.	Refer to Attachment F Atmospheric pressure (psig): 0.007	C
		Oxygen concentration measured (% volume): < 1% Refer to Figure F2	
		Inert gas used: Nitrogen	
7.4.2	Cell vent gas composition was determined using Gas Chromatography (GC)	Refer to Table 8 Refer to Attachment F	C
	Hydrogen gas was measured	Refer to Table 8	C
	The initial atmospheric conditions prior to testing were noted.	Refer to Table 3 Refer to attachment C and F	C
7.4.3	The lower flammability limit of the cell vent gas was determined on samples of the synthetically replicated gas mixture in accordance with ASTM E918, testing at both ambient and cell vent temperatures.	Refer to Table 9 and 10	C

UL 9540A, Edition 4			
Clause	Requirement + Test	Result - Remark	Verdict
7.4.4	The gas burning velocity of the synthetically replicated cell vent gas was determined in accordance with the Method of Test for Burning Velocity Measurement of Flammable Gases Annex in ISO 817.	Refer to Table 9 and 10	C
7.4.5	P_{max} of the synthetically replicated cell vent gas was determined in accordance with EN 15967.	Refer to Table 9 and 10	C
7.6	**Cell Level Test Report Information**		
7.6.1	Minimum information provided in the report for items a) through m)		C
7.6.2	Minimum information of items a) through k) was provided in the report for flow battery		N/A
7.7	**Performance – cell level test**		
7.7.1	a) Thermal runaway cannot be induced in the cell; and	Thermal runaway was achieved in all five cells by external heat applied through flexible film heaters. Refer to attachment C and D.	F
	b) The cell vent gas does not present a flammability hazard when mixed with any volume of air, at both ambient and vent temperatures.	Cell vent gas found to be flammable. Refer to table 8.	F

Table 1 – Specified conditioning parameters			
Charging:		Discharging	
Current (CC), A	39.8	Current (CC), A	39.8
Standard full charge voltage, Vdc	3.65	Voltage at start of discharge, Vdc	3.65
End of charge current, A	7.96	End of discharge voltage, Vdc	2.5
Charging Test Ambient, °C	0 to 45	Discharging Test Ambient, °C	0 to 45
Refer to Attachment A for charge/discharge profiles for each cell.			

Table 2 – Charge completion and cell test initiation times		
Cell Test Number	**Charge Completion Date and Time**	**Cell test Date and Time**
1	2024-06-20, 08:14	2024-06-20, 09:16
2	2024-06-19, 10:09	2024-06-19, 13:44
3	2024-06-20, 08:29	2024-06-20, 10:28
4	2024-06-20, 08:41	2024-06-20, 13:58
5	2024-07-02, 08:50	2024-07-02, 11:26

Table 3 - Test Initiation Details					
	Cell Test 1	**Cell Test 2**	**Cell Test 3**	**Cell Test 4**	**Cell Test 5**
Test Date	2024-06-20	2024-06-19	2024-06-20	2024-06-20	2024-07-02
Test Start Time	09:16	13:44	10:28	13:58	11:26
Initial Lab Temperature	23.0°C	23.0°C	27.5°C	27.5°C	23.0°C
Initial Relative Humidity	80%	86%	63%	61%	66%

Table 4 - Thermal Runaway Results					
	Cell Test 1	**Cell Test 2**	**Cell Test 3**	**Cell Test 4**	**Cell Test 5**
OCV at start of test, Vdc	3.93	3.86	3.95	3.78	3.77
Average Heating Rate, °C/min	6	6	6	6	6
Venting Time after the test start (hh:mm:ss)	00:23:05	00:22:58	00:23:06	00:23:44	00:23:27
Venting Temperature, °C	128.1	129.4	124.4	134.0	132.7
Thermal Runaway Time after the test start (hh:mm:ss)	00:36:55	00:37:56	00:38:32	00:36:20	00:38:16
Thermal Runaway Temperature, °C	207.7	216.9	213.4	200.5	215.9
Refer to Attachment C for surface temperature profiles during testing See attachment E for datasheets					

Table 5 – Average Vent and Thermal Runaway Temperatures	
Average of Cell Vent Temperatures, °C	128.9
Average of Cell Thermal Runaway Temperatures, °C	209.6
#Averages of cell tests other than the gas analysis test	

Table 6 – Parameters Flow Battery	
Single Electrolyte Flow Battery:	N/A
• Volume of Electrolyte Used for Flammability Determination, L	N/A
• Percentage of metal particles representative of fully charged electrolyte (% per volume of test electrolyte)	N/A
• Maximum volume of electrolyte for planned system, L	N/A
Two Electrolyte Flow Battery:	N/A
• Volume of Electrolyte No. 1 Used for Flammability Determination, L	N/A
• Volume of Electrolyte No. 2 Used for Flammability Determination, L	N/A
• Max. volume of electrolyte No. 1 in system, L	N/A
• Max. volume of electrolyte No. 2 in system, L	N/A
Two Electrolyte Flow Battery: Method for charging electrolytes to activate them	N/A
Electrolyte viscosity at 25°C (77°F), m^2/sec of Electrolyte 1	N/A
Electrolyte viscosity at 25°C (77°F), m^2/sec of Electrolyte 2	N/A
ASTM Method to Determine Flash Point:	N/A
Abnormal test methods used for single electrolyte flow battery:	N/A
Abnormal test methods used for two electrolyte flow battery:	N/A
Representative flow battery system used for abnormal testing:	N/A
• Manufacturer:	N/A
• Model No.:	N/A
• Electrical Ratings, Vdc, Ah	N/A
• Total Electrolyte No. 1 Contained, L	N/A
• Total Electrolyte No. 2 Contained, L	

Table 7 – Results of Flammability Testing of Flow Battery Electrolyte	
Flash Point Determined:	N/A
Flash Point Temperature of electrolyte 1, °C:	N/A
Test temperature of electrolyte 1,° C:	N/A
Flash point temperature of electrolyte 2, °C:	N/A
Test temperature of electrolyte 2, °C:	N/A
Two electrolyte flow battery: Maximum temperature measured when mixing electrolytes, °C:	N/A
Maximum electrolyte temperature measured during abnormal testing, °C: • Short circuit test from UL1973:	N/A
• Overcharge test from UL 1973:	N/A

Table 8 – Results of Gas Analysis (Excluding O_2 and N_2)			
Gas		**Measured %**	**Component LFL**[2]
Hydrogen	H2	59.3%	4.0 %
Carbon monoxide	CO	10.0%	10.9 %
Carbon dioxide	CO2	22.4%	-
Methane	CH4	3.68%	4.4 %
Ethane	C2H6	0.53%	2.4 %
Ethylene	C2H4	2.53%	2.4 %
Acetylene	C2H2	0.16%	-
Propane	C3H8	0.12%	1.7 %
Propene (Propylene)	C3H6	0.26%	1.8 %
C4 Total[3]	-	0.40%	-
C5 Total	-	0.12%	-
C6 Total	-	0.39%	-
C7 Total	-	0.04%	-
C8 Total	-	0.06%	-
Benzene	C6H6	0.09%	1.2 %
Toluene	C7H8	0.01%	1.0 %
Xylene	C8H10	0.01%	-
Total	**-**	100	**-**

Table 9 – Gas composition excluding the constituents with boiling points higher than 60°C[4]			
Gas		**Measured %**	**Component LFL**
Hydrogen	H2	59.30	4.0 %
Carbon monoxide	CO	10.00	10.9 %
Carbon dioxide	CO2	22.40	-
Methane	CH4	3.68	4.4 %
Ethane	C2H6	0.53	2.4 %
Ethylene	C2H4	2.53	2.4 %
Acetylene	C2H2	0.12	-
Propane	C3H8	0.12	1.7 %
Propene (Propylene)	C3H6	0.26	1.8 %
C4 Total (n-Butane)	-	0.40	**-**
C5 Total (n-Pentane)	-	0.12	**-**

[2] Extracted LFL values from ISO 10156-2017

[3] Average of n-Butane, 1-Butene, cis-Butene, trans-Butene

[4] The constituents with a higher boiling point were excluded for the flammability characteristic analysis as these components will turn into a liquid state at room temperature and will not release from the gas bottle as a homogenous mixture.

Total	-	100	-

Table 10 – Properties of Vent Gas Analysis	
Lower Flammability limit at Ambient Temperature, 25°C (% vol in air)	7.4
Lower Flammability limit at Vent Temperature, [128.9 °C] (% vol in air)	6.6
~~Flow Batteries, LFL scaled to maximum electrolyte volume of system, 25°C (% vol in air)~~	N/A
~~Flow Batteries, LFL scaled to maximum electrolyte volume of system, [°C] (% vol in air)~~	N/A
Burning Velocity Measurement, S_u cm/sec	85.6
Maximum Pressure P_{max}, psig	98.9

	TABLE: Critical components information				
Object / part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cell Model	LG ENERGY SOLUTION, LTD.	JF2	3.2 Vdc, 159.2 Ah	UL 1973 Annex E	UL Solutions (File Number: MH63736)
Separator	—	—	Generic Material : PE	—	—
Electrolyte	—	—	LiPF6 salt + EC/EMC/DMC solvent	—	—
Case	—	—	Material : Al Pouch Case dimension : 601(L) x 125(W) x 18.1(T)mm, Case material thickness ≦ 0.193mm Case sealing material : PP	—	—

~~**List of test equipment used:**~~

~~A completed list of used test equipment shall be provided in the Test Reports when a Customer's Testing Facility has been used.~~

~~**Clause**~~	~~**Measurement / testing**~~	~~**Testing / measuring equipment / material used, (Equipment ID)**~~	~~**Range used**~~	~~**Last Calibration date**~~	~~**Calibration due date**~~

Attachment A: Cell Conditioning (Charge/discharge) Profiles - (*Pages **17** through **21***)

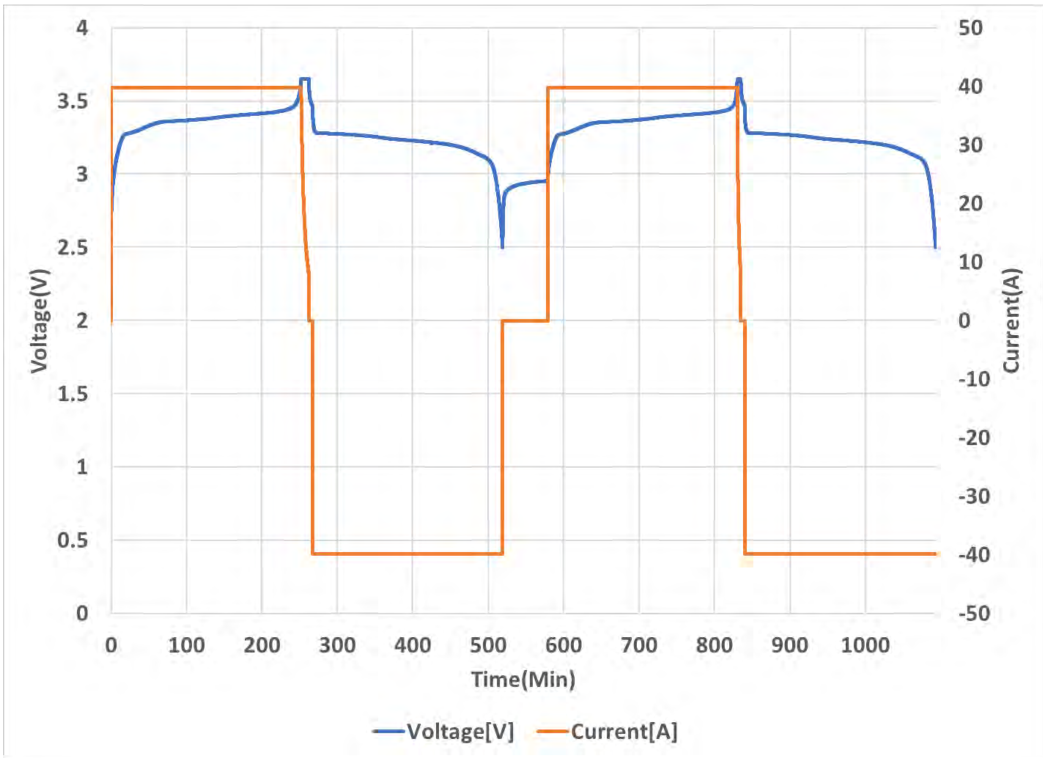


Figure A1: Sample 1 - Cell Conditioning Profile

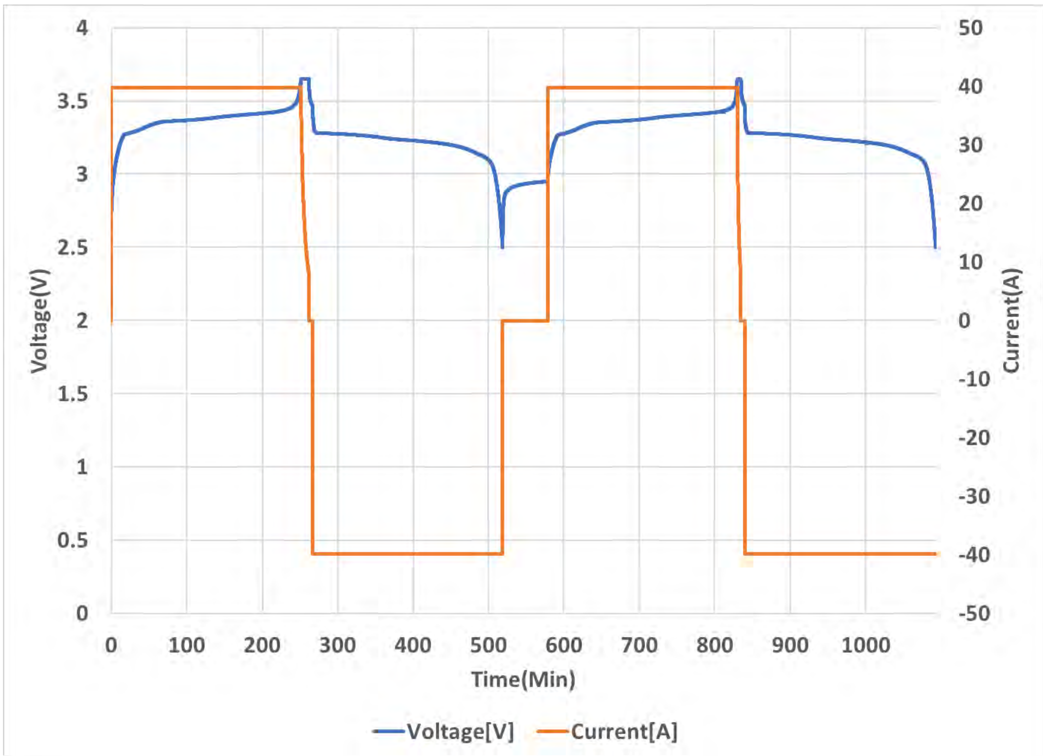


Figure A2: Sample 2 - Cell Conditioning Profile

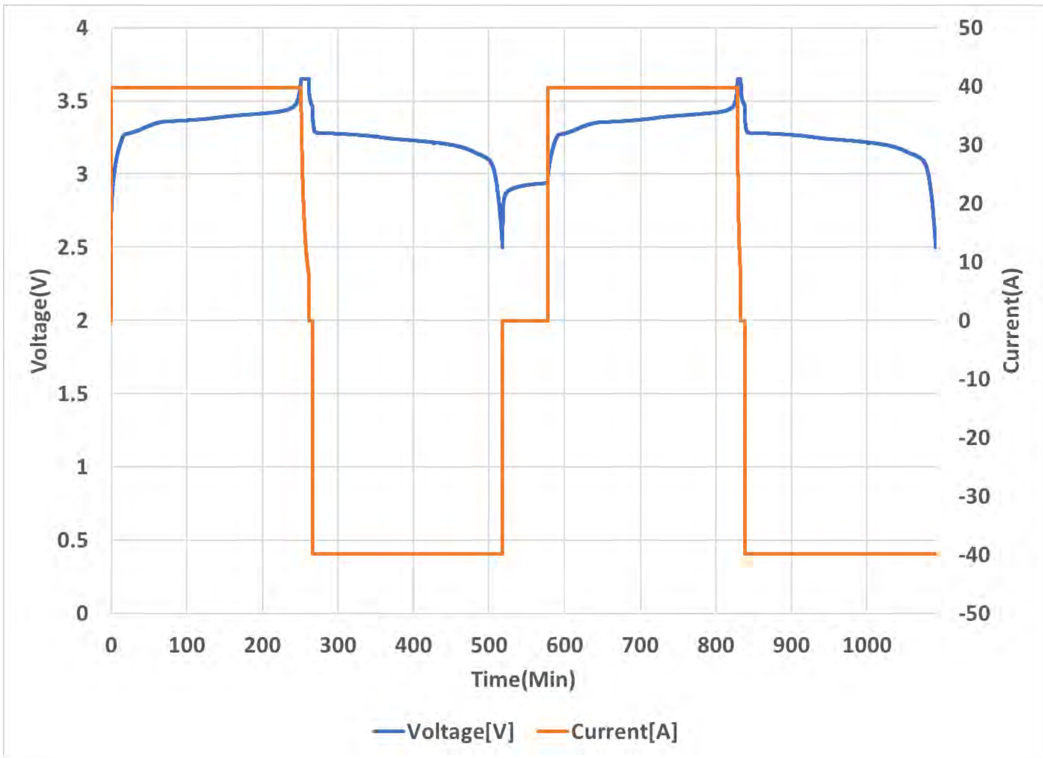


Figure A3: Sample 3 - Cell Conditioning Profile

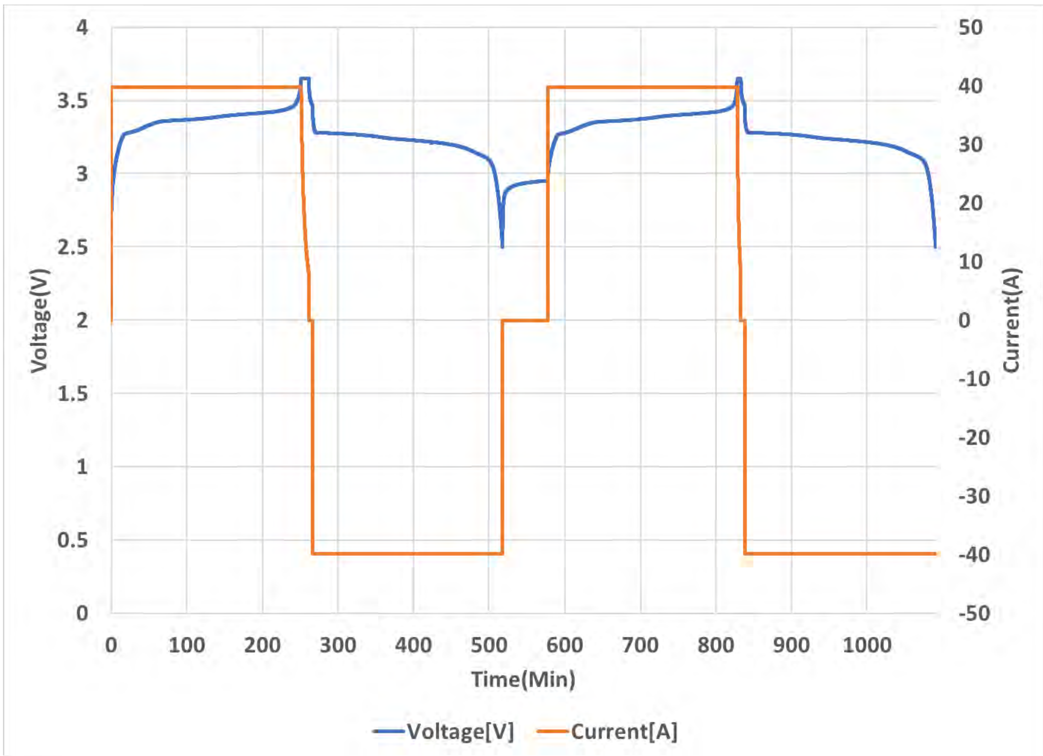


Figure A4: Sample 4 - Cell Conditioning Profile

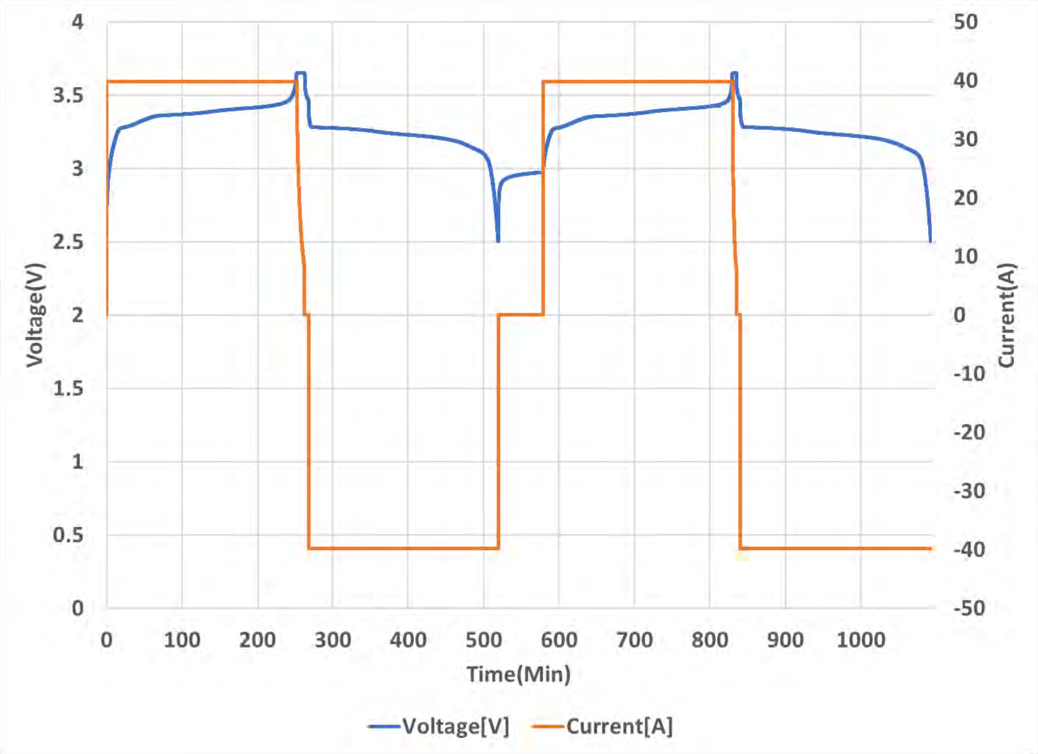


Figure A5: Sample 5 - Cell Conditioning Profile

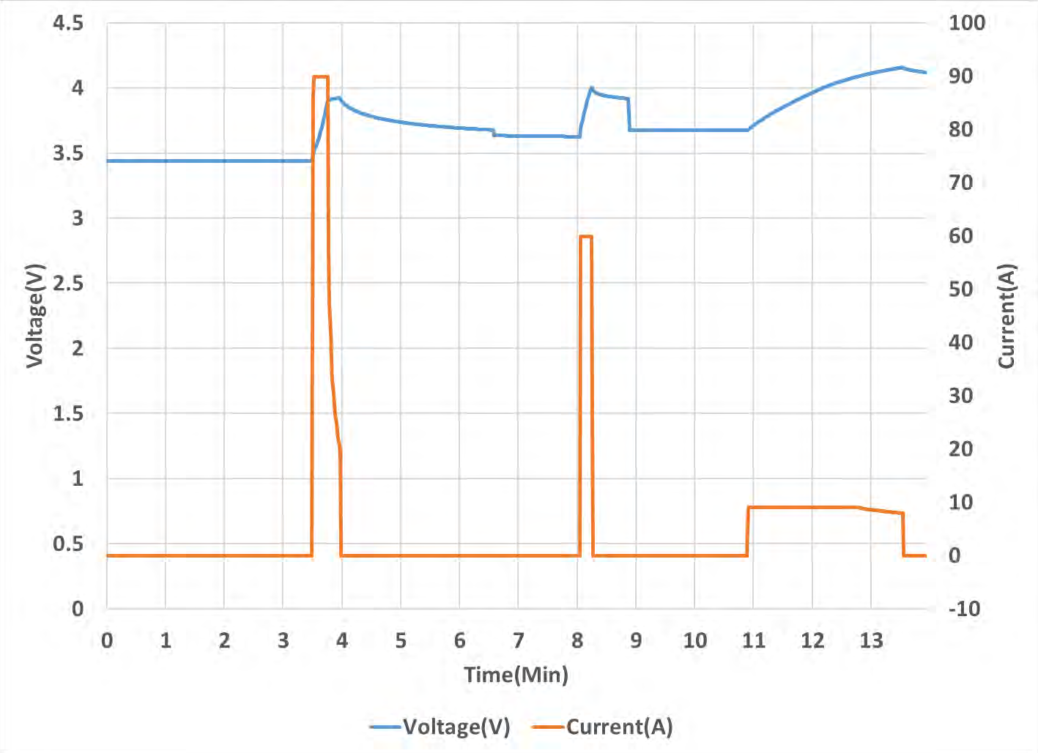


Figure A6: Sample 1- Charging and Topp-off Profile

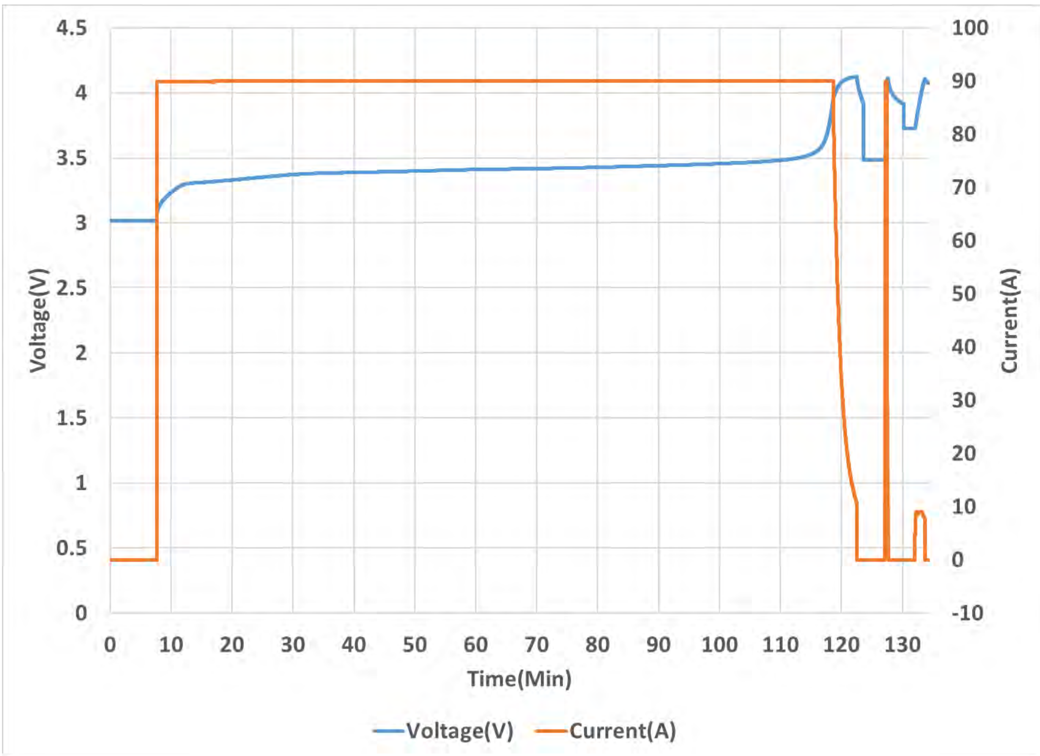


Figure A7: Sample 2- Charging and Topp-off Profile

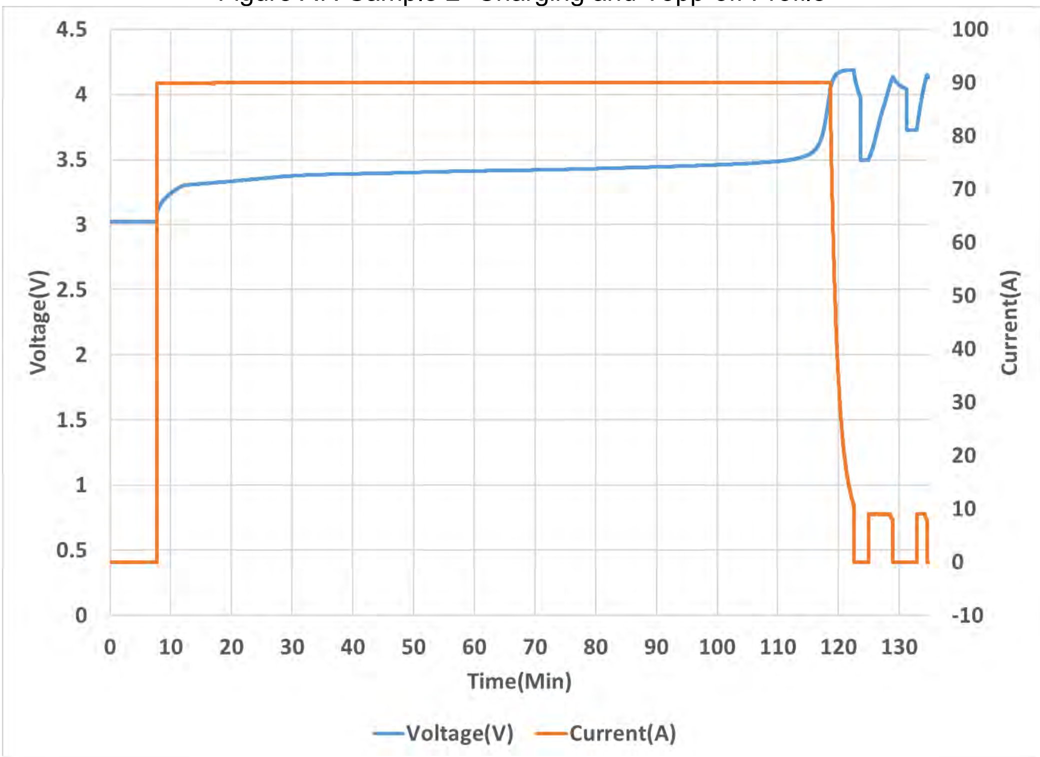


Figure A8: Sample 3- Charging and Topp-off Profile

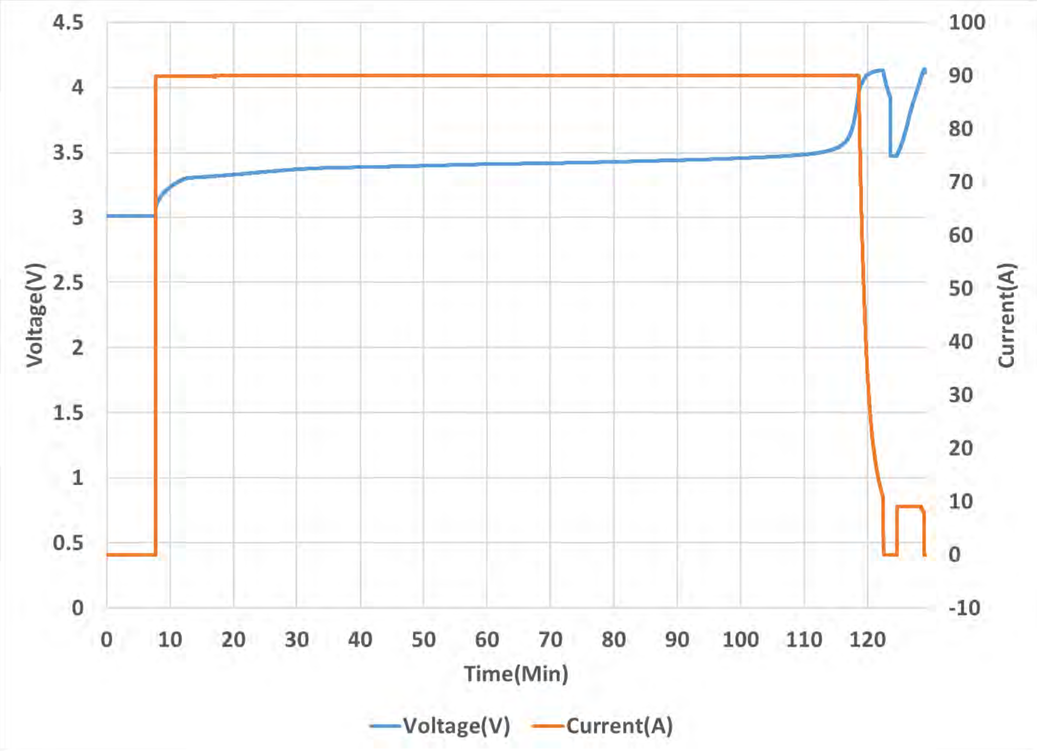


Figure A9: Sample 4- Charging and Topp-off Profile

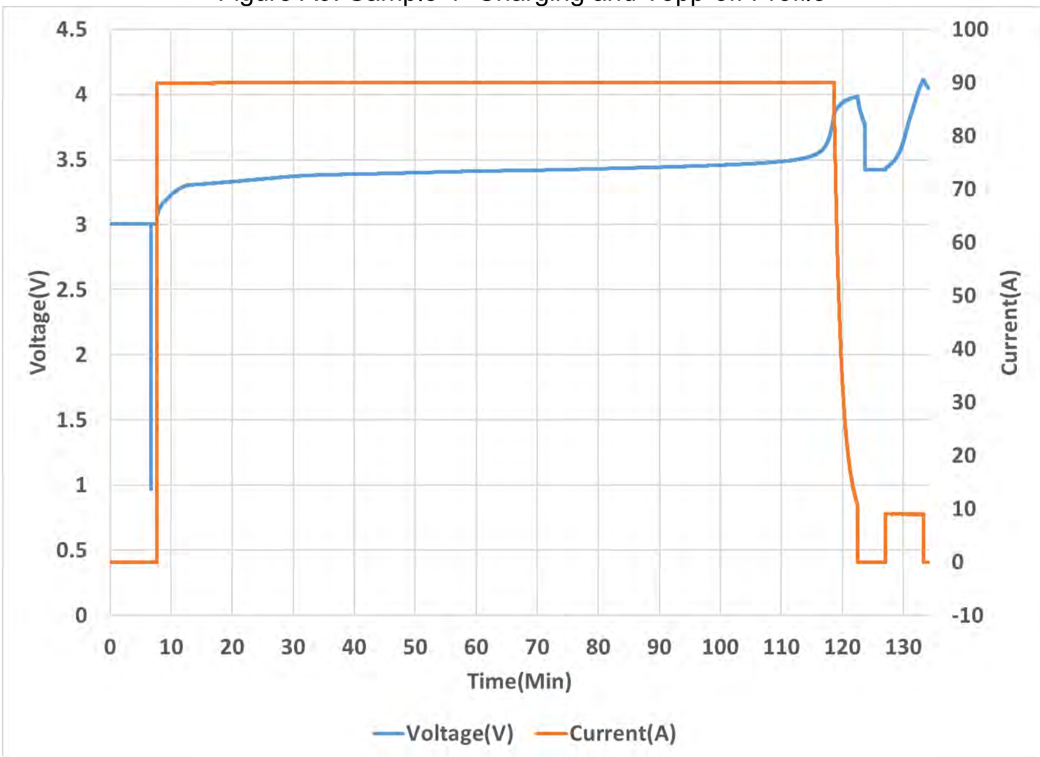
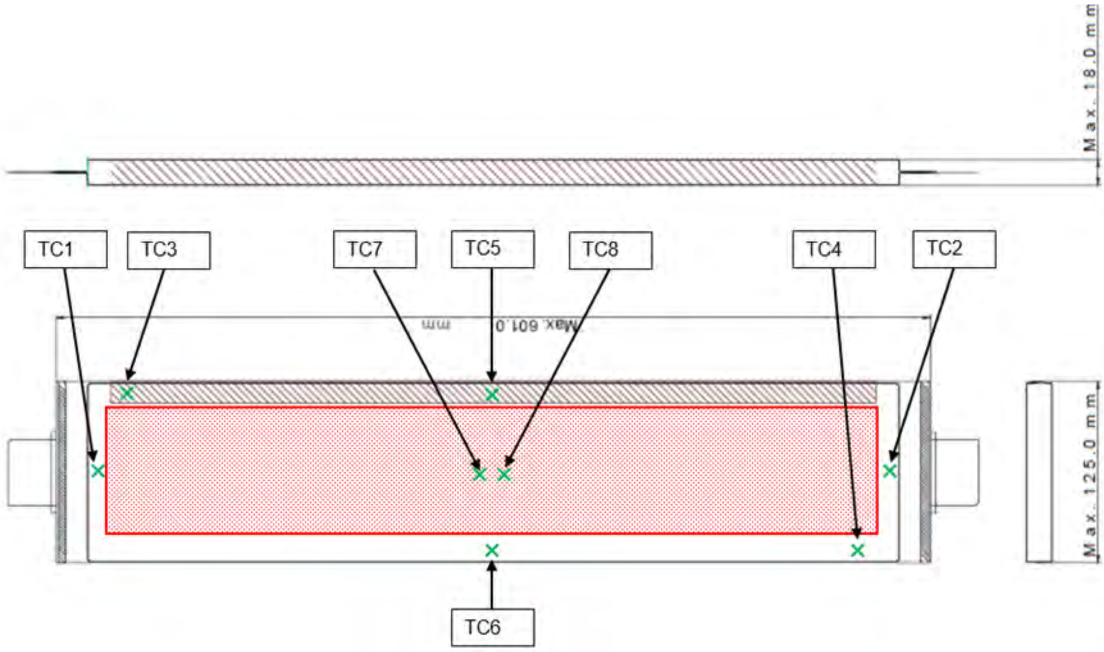


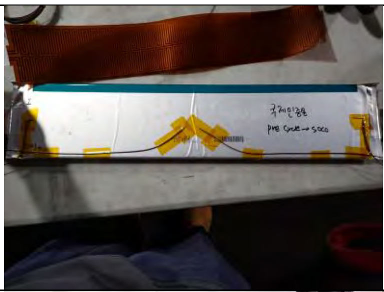
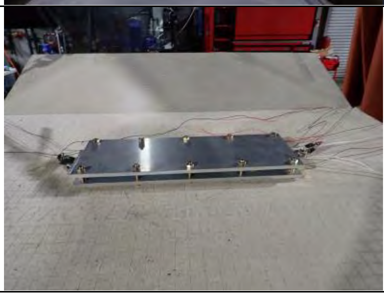
Figure A10: Sample 5- Charging and Topp-off Profile

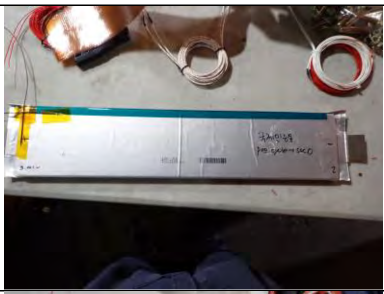
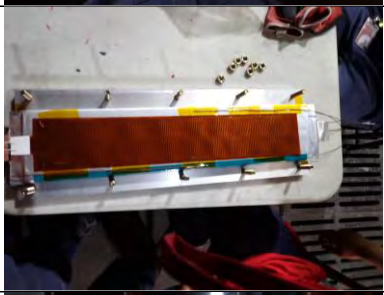
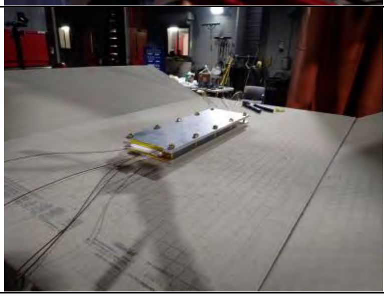
Attachment B: Cell Instrumentation Photos - (*Pages **22** through **27***)

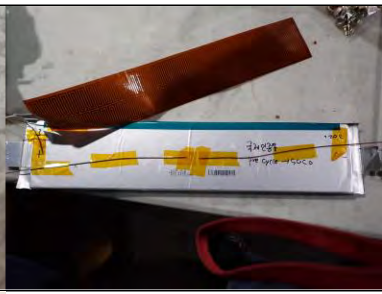
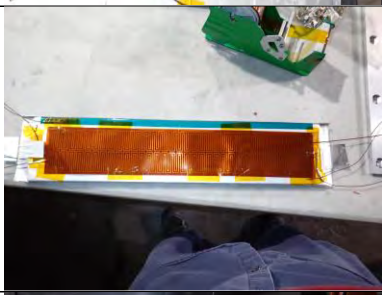
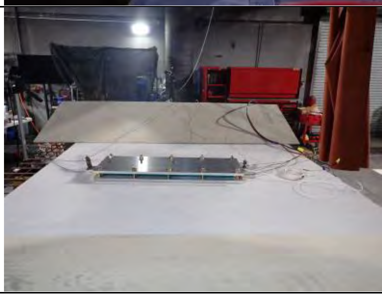


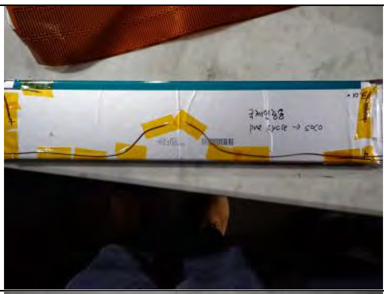
No.	Thermocouple Location
TC1	Positive (+) Terrace
TC2	Negative (-) Terrace
TC3	Positive (+) Cell Body, serves to report venting and thermal runaway temperature
TC4	Negative (-) Cell Body, serves to report venting and thermal runaway temperature back up
TC5	Cell Side
TC6	Cell Side
TC7	Center 1, under heater, heater control
TC8	Center 2, under heater, heater control back up

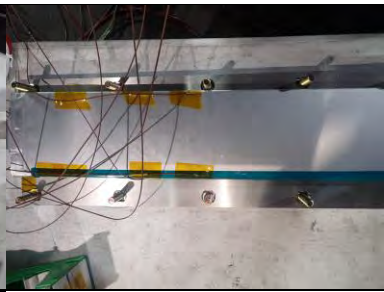
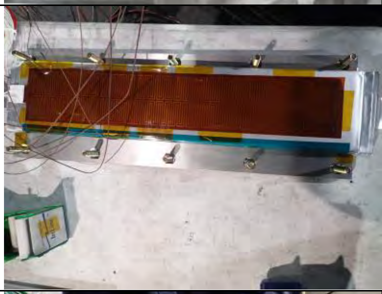
*Note: Red area on the above picture is heater to induce thermal runaway.

Picture description (Cell #1)	Pictures
Cell with the TC	
Cell with the TC & heaters	 
Cell with the jig installed before testing	

Picture description (Cell #2)	Pictures
Cell with the TC	
Cell with the TC & heaters	
Cell with the jig installed before testing	

Picture description (Cell #3)	Pictures
Cell with the TC	 
Cell with the TC & heaters	
Cell with the jig installed before testing	

Picture description (Cell #4)	Pictures
Cell with the TC	
Cell with the TC & heaters	
Cell with the jig installed before testing	

Picture description (Cell #5)	Pictures
Cell with the TC	 
Cell with the TC & heaters	
Cell with the jig installed before testing	 

Attachment C: Cell Temperature Profiles during testing - (*Pages **28** through **30***)

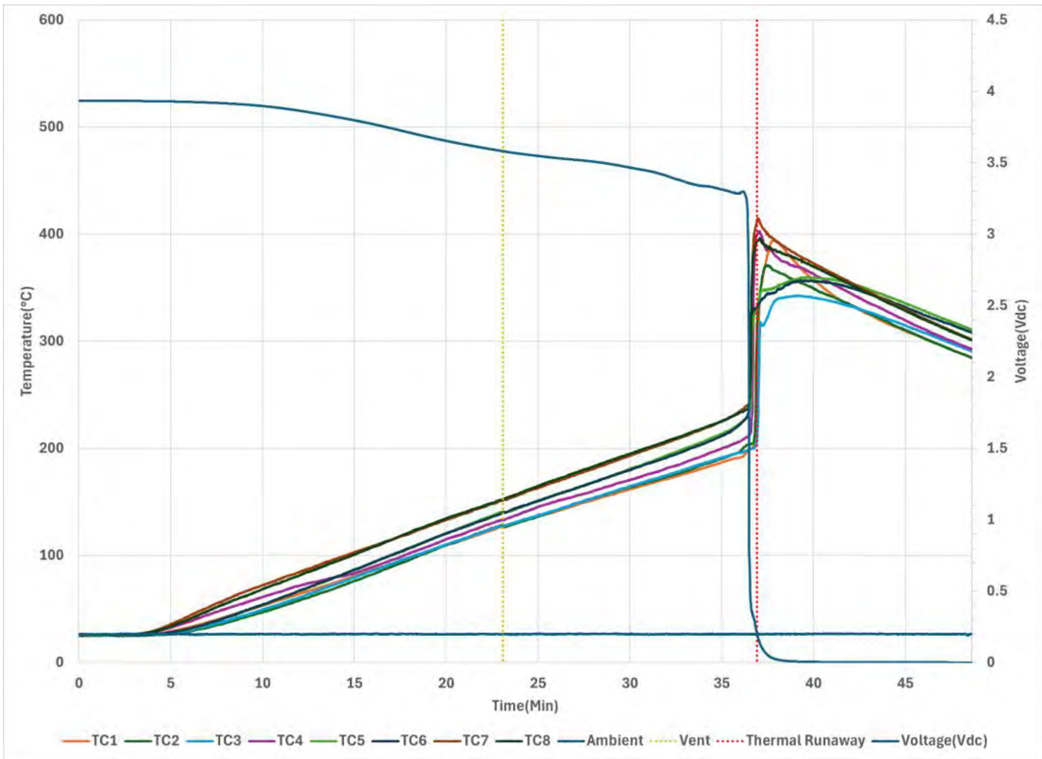


Figure C1: Sample 1 – Thermal Runaway & Vent Temperature

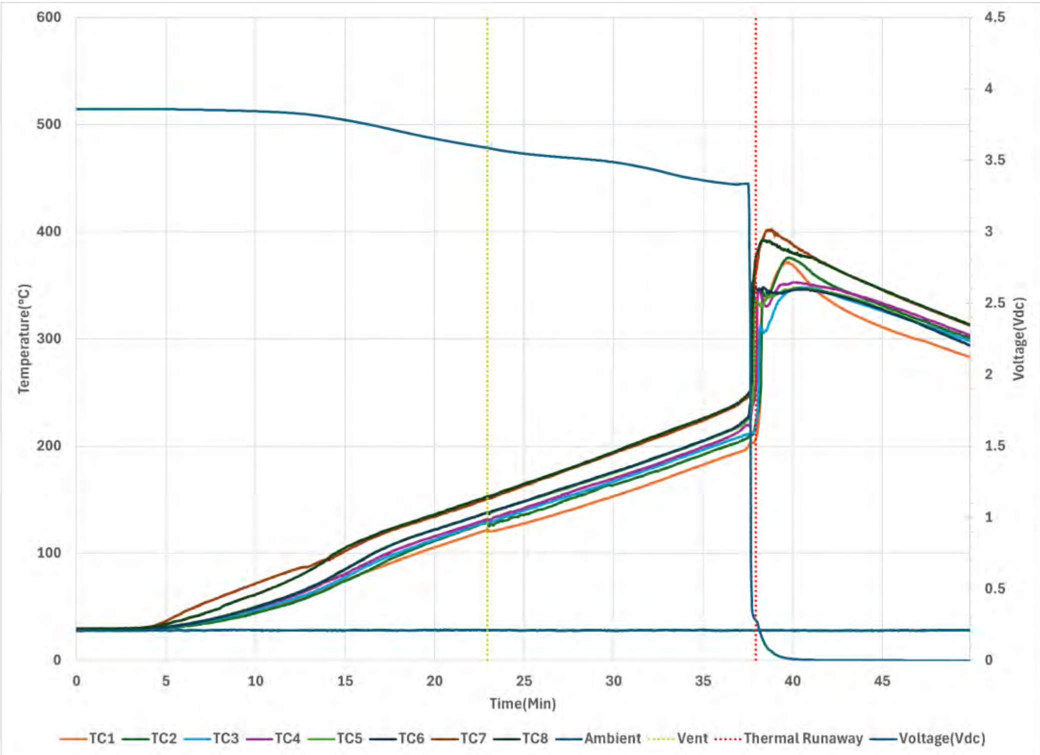


Figure C2: Sample 2 – Thermal Runaway & Vent Temperature

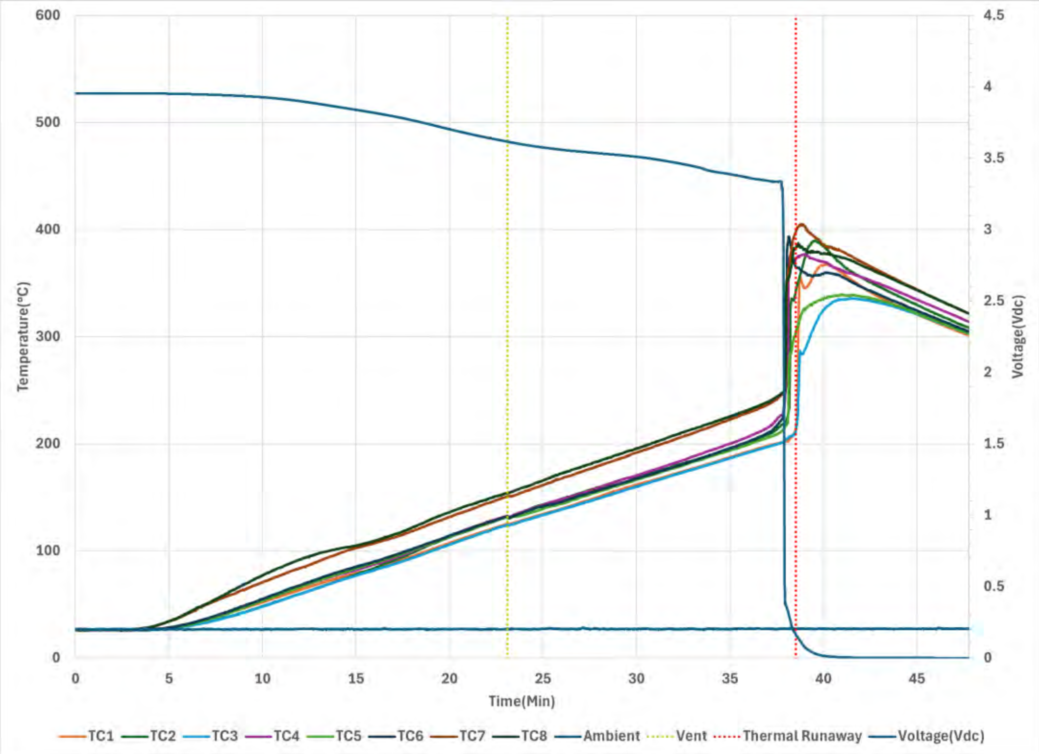


Figure C3: Sample 3 – Thermal Runaway & Vent Temperature

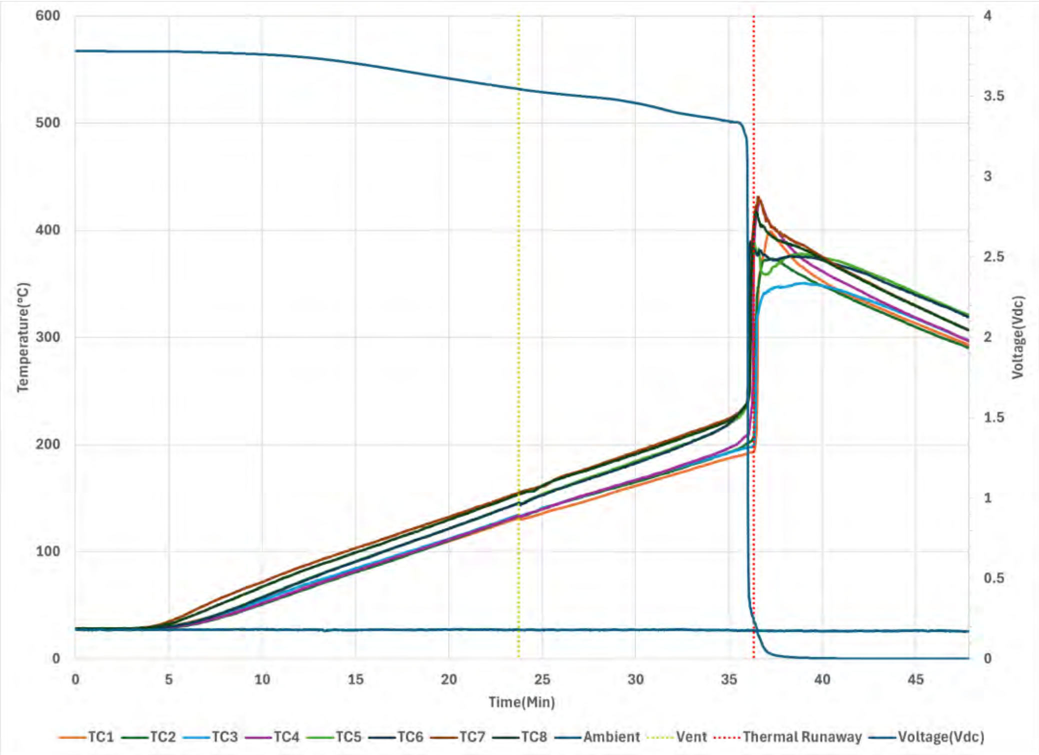


Figure C4: Sample 4 – Thermal Runaway & Vent Temperature

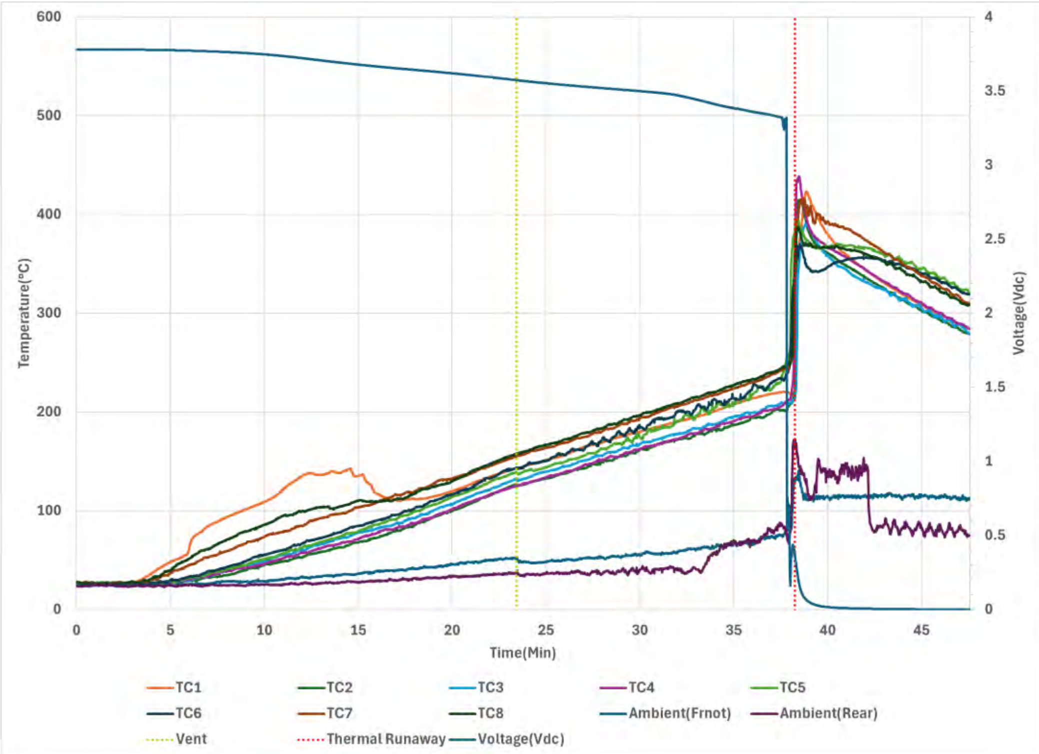
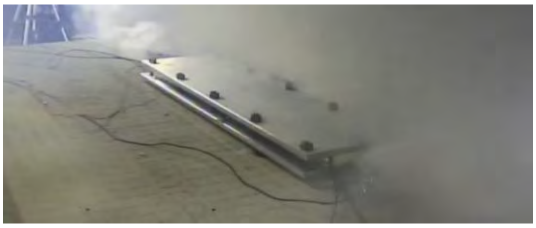
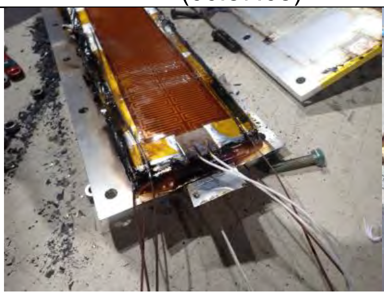
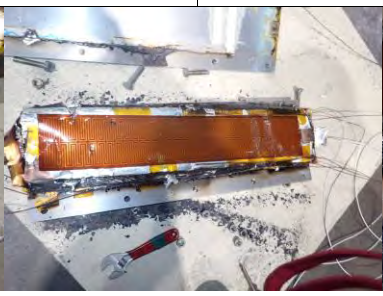


Figure C5: Sample 5 – Thermal Runaway & Vent Temperature

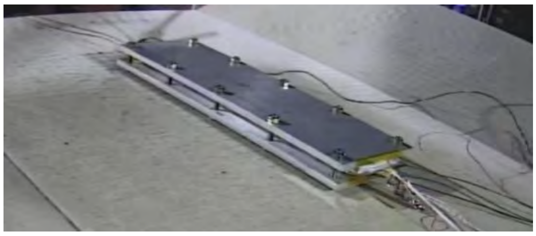
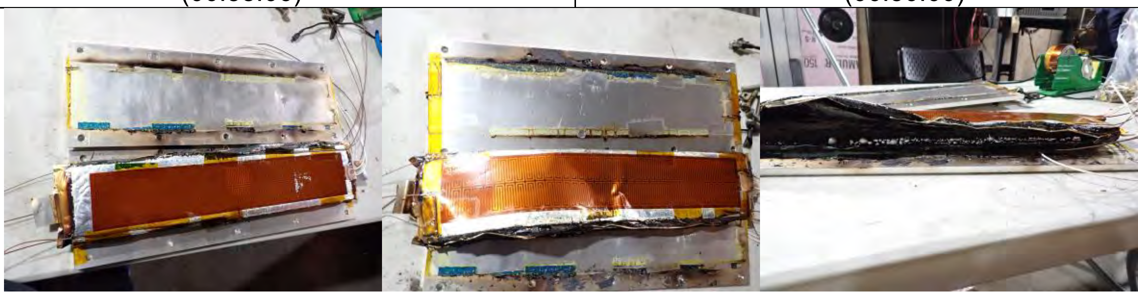
Attachment D: Cell Testing Photos - (*Pages **31** through **35***)

Cell Test 1

	
Cell 1 - *Start of test (00:00:00)	Cell 1 - Venting (00:23:05)
	
Cell 1 – 10 seconds before thermal runaway (00:36:45)	Cell 1 – Thermal runaway** (00:36:55)
	
Cell 1 – 10 seconds after thermal runaway (00:37:05)	Cell 1 – End of test (00:50:00)
  	
Cell 1 - After the end of test (Without Jig)	

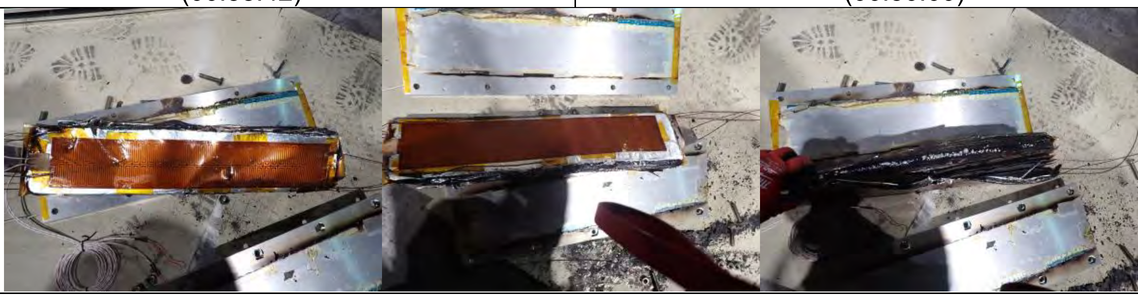
*Note: Plate fixture is the jig for preventing swelling of cell to simulate the constraint in BESS Modules.
**Note: Thermal runaway was determined when the temperature of the cell surface increased in an uncontrollable manner.

Cell Test 2

	
Cell 2 - *Start of test (00:00:00)	Cell 2 - Venting (00:22:58)
	
Cell 2 – 10 seconds before thermal runaway (00:37:46)	Cell 2 – Thermal runaway** (00:37:56)
	
Cell 2 – 10 seconds after thermal runaway (00:38:06)	Cell 2 – End of test (00:50:00)
	
Cell 2 - After the end of test (Without Jig)	

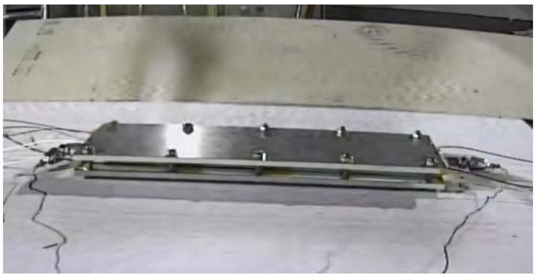
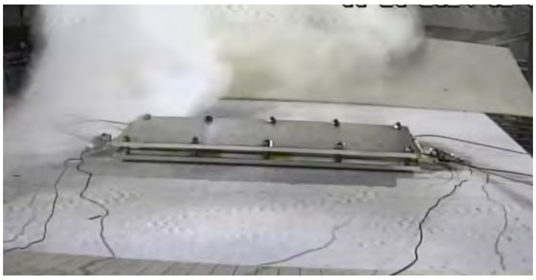
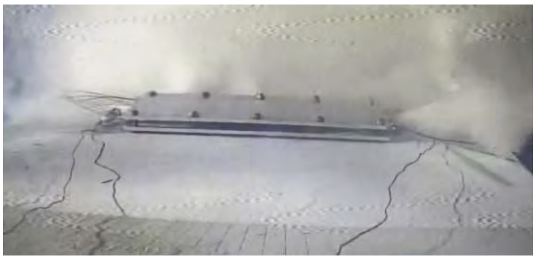
*Note: Plate fixture is the jig for preventing swelling of cell to simulate the constraint in BESS Modules.
**Note: Thermal runaway was determined when the temperature of the cell surface increased in an uncontrollable manner.

Cell Test 3

	
Cell 3 - *Start of test (00:00:00)	Cell 3 - Venting (00:23:06)
	
Cell 3 – 10 seconds before thermal runaway (00:38:22)	Cell 3 – Thermal runaway** (00:38:32)
	
Cell 3 – 10 seconds after thermal runaway (00:38:42)	Cell 3 – End of test (00:50:00)
	
Cell 3 - After the end of test (Without Jig)	

*Note: Plate fixture is the jig for preventing swelling of cell to simulate the constraint in BESS Modules.
**Note: Thermal runaway was determined when the temperature of the cell surface increased in an uncontrollable manner.

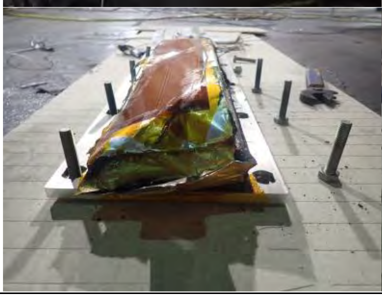
Cell Test 4

	
Cell 4 - *Start of test (00:00:00)	Cell 4 - Venting (00:23:44)
	
Cell 4 – 10 seconds before thermal runaway (00:36:10)	Cell 4 – Thermal runaway** (00:36:20)
	
Cell 4 – 10 seconds after thermal runaway (00:36:30)	Cell 4 – End of test (00:50:00)
	
Cell 4 - After the end of test (Without Jig)	

*Note: Plate fixture is the jig for preventing swelling of cell to simulate the constraint in BESS Modules.
**Note: Thermal runaway was determined when the temperature of the cell surface increased in an uncontrollable manner.

Cell Test 5

Video was not recorded because this cell was placed inside the gas collection vessel.

Picture description (Cell #5)	Pictures
Cell with the jig installe d before testing	 
After the end of test (Without Jig)	   

Attachment E: Cell Test Datasheets - (*Pages **36** through **36***)

Cell Test Datasheet is stored in the UL database.

Attachment F: Cell vent gas test chamber photo and profile of chamber gas analysis (O_2 and Pressure) - (*Pages **37** through **38***)

This attachment depicts the equipment used to capture the vented gases.

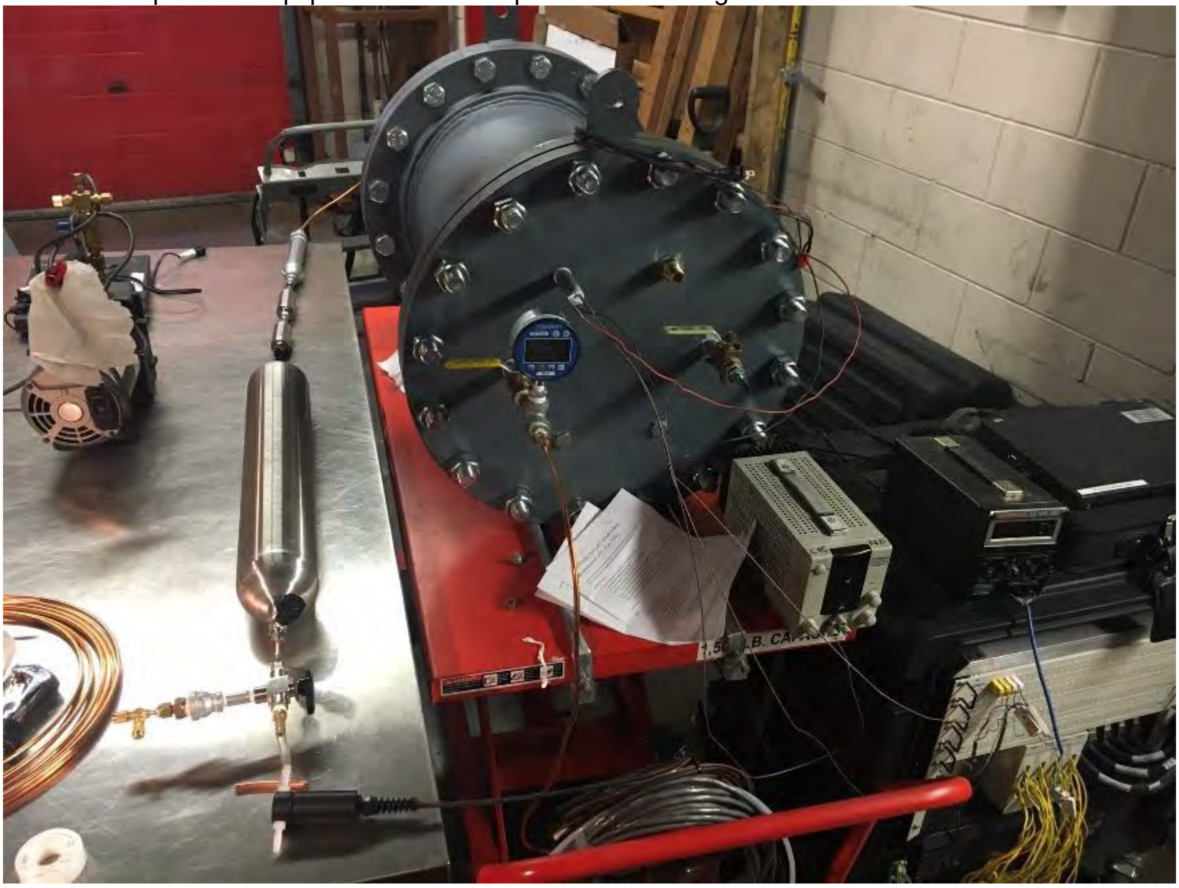


Figure F1: Gas Collection Chamber Test Set-up

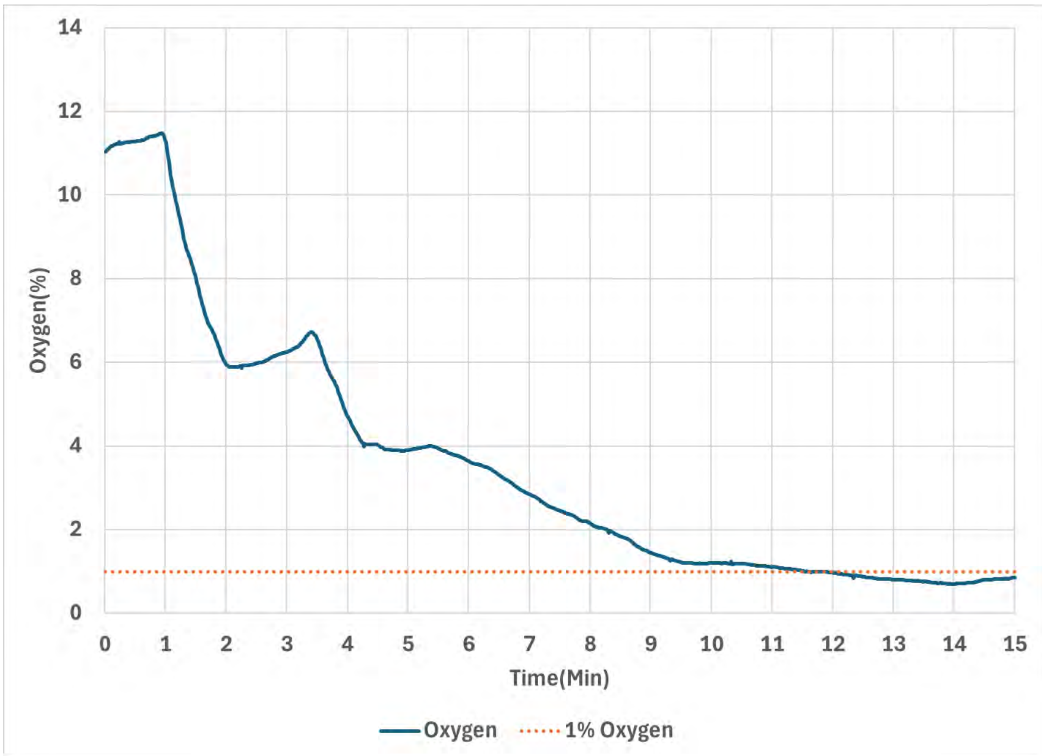


Figure F2: Gas Collection Chamber – Concentration Profile during Oxygen Purge

Attachment G: Certification Requirements Decision - (*Pages **39** through **39***)

UNDERWRITERS LABORATORIES INC. CERTIFICATION REQUIREMENT DECISION

This Certification Requirement Decision is prepared by UL LLC. It is normative for the applicable UL Product Certification Program(s); however, it is currently not part of the UL Standard(s) referenced below.

Product Category (CCN): AACD
Standard Number: UL 9540A
Standard Title: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Edition Date: November 12, 2019
Edition Number: 4
Section / Paragraph Reference: 7.3.1.5
Subject: Option to do a continuous thermal ramp until thermal runaway

DECISION:

7.3.1.5 Before beginning the test, a surface temperature shall be determined to approximate the temperature at which internal short circuiting within the cell will occur that could lead to a thermal runaway condition. For Li-ion cells, the surface temperature hold point shall be between 5°C (9°F) and 15°C (27°F) greater than the melting temperature of the cell separator material as determined from differential scanning calorimetry (DSC) data of the separator in accordance with UL 2591 (UL 746A). Thermal runaway may occur before this hold point temperature range is reached. However, if thermal runaway is not achieved at this hold point temperature after a period of 4 h, the cell heating rate according to 7.3.1.2 shall be reestablished until thermal runaway occurs or it is demonstrated that thermal runaway is not achievable by heating.

Exception: If the separator information is not available or at the manufacturer's discretion, the thermal ramp can be conducted continuously without a hold point until thermal runaway.

RATIONALE FOR DECISION:

The cell failure method had always been a thermal ramp until thermal runaway occurred. The hold temperature was established because of concern that if the thermal ramp continued at too high of a temperature, it may melt the cell casing. However, the separator information may not always be available and it may be just easier to conduct the test with a continuous thermal ramp if the client is in agreement. In either case, the goal is to establish a thermal runaway condition.

<Certification Requirement Decision dated on 2020-05-20>

MODULE TEST REPORT
UL 9540A
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)

Project Number. ....:	**4791519232**
Date of issue....................................:	**2024.12.26**
Total number of pages ....:	**27**
UL Report Office ....:	**UL SOLUTIONS, KOREA**
Applicant's name ....:	LG ENERGY SOLUTION, LTD.
Address..:	188, MUNJI-RO, YUSEONG-GU DAEJEON, 34122 REPUBLIC OF KOREA
Test specification:	4th Edition, Section 8, November 12, 2019
Standard..:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure ....:	8.1 – 8.4
Non-standard test method ....:	N/A

Cell level information	
Cells in Module:	
•Manufacturer Name	LG Energy Solution, Ltd.
•Part Number	JF2
•Chemistry	Lithium Iron Phosphate
•Format	Pouch
Ratings (Vdc, Ah) :	3.2 Vdc, 159.2 Ah
Was the cell certified? :	Yes
Standard the cell was certified to:	UL 1973, Annex E
Organization that certified the cell:	UL Solutions (UL File #: MH63736)
Average cell surface temperature at gas venting, °C:	128.9
Average cell surface temperature at thermal runaway, °C:	209.6
Gas Volume:	64.0
Lower flammability limit (LFL), % volume in air at the ambient temperature:	7.4
Lower flammability limit (LFL), % volume in air at the venting temperature:	6.6
Burning velocity (S_u) cm/s:	85.6
Maximum pressure (P_{max}) psig:	98.9

Cell Gas Composition:

Gas	Measured %
Hydrogen	59.3
Carbon monoxide	10.0
Carbon Dioxide	22.4
Methane	3.68
Ethane	0.53
Ethylene	2.53
Acetylene	0.16
Propane	0.12
Propene (Propylene)	0.26
C4 Total	0.40
C5 Total	0.12
C6 Total	0.39
C7 Total	0.04
C8 Total	0.06
Benzene	0.09
Toluene	0.01
Xylene	0.01
Total	**100**

Module level Information	
Model No:	EP096636PFB1
Ratings (Vdc, Ah):	96.0 Vdc, 636.8 Ah
Module cell configuration (xS/yP) ......:	30S/4P
Module dimensions (W x D x H (mm)) :	825.0 x 2085.0 x 145.0
Module weight (kgs) :	Max 410 kg
Module enclosure material :	Front plate & Rear plate: Steel, Min 1.0 mm Top plate: Steel, Min 1.0 mm Bottom plate: Aluminium, Min 1.5 mm Side Plate: Aluminium, Min 3.5 mm Front cover: Polycarbonate (PC), Min 2.5 mm
Was the module certified? :	No
Standard the module was certified to:	--
Organization that certified test item:	--

Cell failure test method performed for the module level (summary of method and test clause):

☒ External heating using thin film with 4°C to 7°C thermal ramp.
☐ Nail Penetration☐ Overcharge
☐ External short circuit (***X*** Ω *external resistance*)
☐ Others

Description of method used to fail cells if other than external thin film heater with thermal ramp: N/A

Description of components employed within the module that serve to supress propagation (fire protection features).

A module consists of a total of three CMAs (i.e., Cell Module Assembly) and, each CMA has a total 40 cells. For suppression against propagation from Thermal Runaway, there are three aerogel pads in each CMA, and a Mica sheet is between CMA and CMA. Please refer to Attachment C in this report.

Number of initiating cells failed to achieve propagation.	1
Thermal Runaway Propagation:	Yes
Maximum Smoke Release Rate (m^2/s)	2.29
Total Smoke Released: (m^2)	707.75
Total smoke released duration	From 00:24:47 to 3:00:00
Peak Chemical Heat Release Rate: (kW):	No flaming observed
External Flaming:	No
Location(s) of Flame Venting:	No flaming observed
Flying Debris:	No flying debris observed
Re-ignitions:	No re-ignition

Summary of Module level test Gas Analysis Data:

Gas Analysis:

☒ **Flame ionization detection**

☐ **Fourier-Transform infrared Spectrometer**

☒ **Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)**

☒ **White light source with photo detector (smoke release rate)**

- **Gas Composition & Volume for Each Compound (Pre-flaming and After flame):**

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	435.21	No flaming	0.05
Carbon Dioxide	Carbon Containing	352.99	No flaming	0.64
Carbon Monoxide	Carbon Containing	134.14	No flaming	0.07
Hydrogen	Hydrogen	422.97	No flaming	4.10

Summary of Module testing:

Performance Criteria in accordance with Clause 8.4 and Figure 1.1:

[X] The effects of thermal runaway was contained by the module design;

[ ] Cell vent gas (based upon the cell level test) was non-flammable

Necessity of a unit level test

[X] The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 4th edition has not been met, therefore unit level testing in accordance with UL 9540A will need to be conducted on a complete unit employing this module.

[N/A] ~~The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 4th edition has been met, therefore unit level testing in accordance with UL 9540A need not be conducted.~~

Testing Laboratory information

Testing Laboratory and testing location(s):

Testing Laboratory:	UL Solutions	
Testing location/ address ....:	SOUTH CHINA TESTING AND CERTIFICATION CO LTD / Li Kou Section Guangshan Road, Zengjiang Street, Zengche District,Guangzhou, Guangdong, CN	
Tested by (name, signature) ....:	Ali, Lin	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) ....:	N/A	N/A
Project Handler (name, signature)...............:	Donghyun Kim	Donghyun Kim
Reviewer (name, signature) ....:	Benjamin Liu	Benjamin Liu

List of Attachments (including a total number of pages in each attachment):
Attachment A: Module Conditioning (Charge/discharge) Profiles - (*Pages **16** through **16***)
Attachment B: Module Construction Photos - (Pages ***17*** through ***17***)
Attachment C: Module Instrumentation Photos - (*Pages **18** through **20***)
Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing - (*Pages **21** through **22***)
Attachment E: Module Testing Photos - (*Pages **23** through **23)***
Attachment F: Module Test Datasheets - (*Pages **24** through **25)***
Attachment G: Module Gas Flow Rate and Heat Release Profiles - (*Pages **26** through **27***)

Photo(s) of module:

Test Item Charge/Discharge Specifications:	
• **Charge Power, W/ ~~current~~, ~~A~~:**	15,283
• **Standard Full charge Voltage, Vdc:**	109.5
• **Charge temperature range, °C:**	0 ~ 40
• **End of charge current, A:**	N/A
• **Discharge Power, W/ ~~current~~, ~~A~~:**	15,283
• **End of discharge voltage, Vdc:**	75.0
• **Discharge temperature range, °C:**	0 ~ 40

Test item particulars... :	
Possible test case verdicts:	
- test case does not apply to the test object...........:	N/A
- test object does meet the requirement..................:	P (Pass)
- test object does not meet the requirement...........:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Testing...:	
Date of receipt of test item ....:	2024-10-15
Date (s) of performance of tests ....:	2024-10-17

General remarks:

"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.

Throughout this report a point is used as the decimal separator.

Manufacturer's Declaration of samples submitted for test:

The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided ....:	☐ **Yes** ☒ **Not applicable**
Name and address of factory (ies) ....:	NANJING ZHONGSHAN ELECTRONICS Co., Ltd. No 18 Yihu Road, Lishui Economic Development Zone, Lishui County, Nanjing, Jiangsu Province, China 211200

General product information and other remarks:

The EP096636PFB1 is a lithium iron phosphate battery module manufactured by LG Energy Solution. The cell model is JF2 Cell rated 3.20 Vdc and 159.2 Ah manufactured by LG Energy Solution. This module has an 30S4P cell configuration and is rated as nominal voltage 96.0 Vdc, 636.8 Ah.

5.0	CONSTRUCTION		Verdict
5.2	**Module Construction**	--	—
5.2.1, 5.2.3	Construction information	See Test Item Description at the beginning of this report	—
	General layout of module contents	See Attachment B	—
5.2.2	Module certified to UL 1973	Not certified to UL1973	N/A
	Organization that certified module:	--	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**	--	--
8.1	**Samples**	--	--
8.1.1	Samples conditioned through charge discharge cycling a minimum of 2 cycles.	See Attachment A for profiles. See Table 1 for specifications. See also Table 2.	C
8.1.2	100% SOC and stabilize from 1h to 8 h before testing		
8.1.3	Electronic controls such as BMS not relied upon during testing.	BMS was not relied upon during the testing.	C
8.2	**Test Method**	--	--
8.2.1	Ambient indoor laboratory conditions: 25 ±5°C (77 ±9°F) ≤50 ±25% RH at the initiation of the test.	See Table 3.	C
8.2.2	Test conducted under a smoke collection hood appropriately sized for the module	Complied.	C
8.2.3	The weight of the module was recorded before and after testing, (kg)	See Table 10.	C
8,2,4	A sufficient number of cells were forced into thermal runaway to create a condition of cell to cell propagation within the module.	See Attachment C. See Tables 4 and 5	C
	The location of the cell(s) forced into thermal runaway were selected to present the greatest thermal exposure to adjacent cells	See Attachment C for figures showing location within the module of the cell(s) forced into thermal runaway.	C
8.2.5	The method used to initiate thermal runaway in the cell(s) were in accordance with 7.2	See Summary of Cell Testing at the beginning of this report.	C
8.2.6	The occurrence of thermal runaway was verified	See Test Results from Cell Level Test from the beginning of this report. See Attachments D.	C

8.2.7	The module was placed on top of a non-combustible horizontal surface with the module orientation representative of its intended final installation.	See Attachment C.	C
8.2.8	The chemical heat release rate of the module was measured with oxygen consumption calorimetry	See Table 10 See Attachment F.	C
8.2.9	The chemical heat relate rate was measured for the duration of the test	See Attachment F.	C
8.2.10	The chemical heat release rate was measured using the following equipment: • Paramagnetic oxygen analyser • Non-dispersive infrared carbon dioxide and carbon monoxide analyser • Velocity probe • Type K thermocouple	See Attachment F.	C
	The instrumentation was located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influences of bends or exhaust devices.	Complied.	C
8.2.11	The chemical heat release rate at each of the flows was calculated in accordance with 8.2.11.	See Attachment F	C
8.2.12	The hydrocarbon content of the vent gas was measured using flame ionization detection.	See Table 8 and 9.	C
	Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.	See Table 8.	C
8.2.13	The hydrocarbon content of the vent gas may also be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer.	See Attachment G. Fourier-Transform Infrared Spectrometer was not used in accordance with Certification Requirement Decision.	C
	Vent gas velocity and temperature measurements respectively were obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.	Complied.	C
8.2.14	The light transmission in the exhaust duct of the heat release rate calorimeter was measured using a white light source and photo detector for the duration of the test.	Complied.	C
8.2.15	Smoke release rate was calculated as outlined in 8.2.15	See Table 10 See Attachment F	C
8.3	**Module level test report**	--	--

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	a. Module manufacturer and model number; b. Number of cells in module; c. Module configuration;	See Test Item Description in beginning of this report.	C
	d. Module construction features;	See Attachment B. See Critical Components Table.	C
	e. Module voltage corresponding to the tested SOC;	See Table 3.	C
	f. Thermal runaway initiation method used;	See Attachment C.	C
	g. Heat release rate versus time data;	See Table 9.	C
	h. Flammable gas generation and composition data;	See Attachment F. See Tables 8 and 9.	C
	i. Peak smoke release rate and total smoke release data.	See Table 9. See Attachment F.	C
	j. Observation(s) of flying debris or explosive discharge of gases;	See Attachment E and Table 11.	C
	k. Observation(s) of sparks, electrical arcs, or other electrical events;	See Attachment E and Table 11.	C
	l. Identification/location of cells(s) that exhibited thermal runaway within the module;	See Tables 4 and 5.	C
	m. Locations and visual estimations of flame extension and duration from the module;	See Attachments E. See Table 7.	C
	n. Module weight loss;	See Table 10.	C
	o. Video of the test.	Videos provided to the customer.	C
8.4	**Performance – Module level**	--	--
8.4.1	The following performance conditions are met during the module level test: a) Thermal runaway is contained by module design;	No external flaming observed.	C
	b) Cell vent gas is nonflammable as determined by the cell level test	The vent gas is flammable.	F

Table 1 – Specified conditioning parameters			
Charging:		**Discharging:**	
Power (CP), W / ~~Current (CC), A~~	15,283	Power (CP), W / ~~Current (CC), A~~	15,283
Standard full Charge Voltage, Vdc	109.5	End of discharge voltage, Vdc	75.0
End of charge current, A	N/A	Discharging Test Ambient, °C	0 ~ 40
Charging Test Ambient, °C	0 ~ 40		
Refer to Attachment A for charge/discharge profiles for the module.			

Table 2 – Charge completion and module test initiation times	
Charge Completion Date and Time	**Module Test Date and Time**
2024-10-17, 06:51:36	2024-10-17, 14:15:00

Table 3 - Test Initiation Details	
Test Date	2024-10-17
Test Start Time	14:15:00
Initial Lab Temperature	30.2
Initial Relative Humidity	61.2
Module OCV at Start of Test, Vdc	101.92

Table 4 – Approximate time of thermal runaway propagation through module	
Time to thermal runaway	**Location**
00:27:14	Thermal Runaway on Initiating Cell (Cell 11)
00:31:00	Thermal Runaway on Cell 8
00:38:44	Thermal Runaway on Cell 4

Table 5 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	Test was initiated – The initiating cell temperature was increased at a rate of 4 °C/min to 7 °C/min until thermal runaway occurred.
00:24:47	Vent (Cell 11)	Initiating cell (Cell 11) vent – Gas from the module was not observed in video. However, temperature of the initiating cell was suddenly decreased based on data of thermocouples. The vent temperature was 133.1 °C.
00:27:14	Thermal Runaway (Cell 11)	Temperature of the initiating cell (Cell 11) was increased in an uncontrolled manner based on data of thermocouples. Also, a lot of gas came out of the module in video. The thermal runaway temperature was 154.2°C.
00:31:00	Thermal runaway Propagation on-going	The Cell 8 went into thermal runaway by thermal runaway propagation occurred from the initiating Cell (Cell 11).
00:38:44	Thermal runaway Propagation on-	The Cell 4 went into thermal runaway by thermal runaway propagation occurred from the initiating Cell (Cell 11).

	going	
06:34:59	Test terminated	Data recording was stopped past 06:34:59 since the test started. The test sample remained in the testing room overnight. No further thermal runaway or re-ignition was observed.

Table 6 – Gases measured and measurement methods used in unit level testing			
Measurement Method	**Gases Measured**	**Chemical Formula**	**Gas Type**
Flame Ionization Detection (FID)	Total Hydrocarbons	-	Hydrocarbons
Solid-state Hydrogen Sensor	Hydrogen	H_2	
Non-dispersive infrared spectroscopy (NDIR)	Carbon Dioxide	CO_2	Carbon Containing
	Carbon Monoxide	CO	Carbon Containing
~~[ ] Fourier Transform Infrared Spectrometer (FTIR)~~	~~Acetylene~~	~~C_2H_2~~	~~Hydrocarbons~~
	~~Ethylene~~	~~C_2H_4~~	~~Hydrocarbons~~
	~~Methane~~	~~CH_4~~	~~Hydrocarbons~~
	~~Methanol~~	~~CH_3OH~~	~~Hydrocarbons~~
	~~Propane~~	~~C_3H_8~~	~~Hydrocarbons~~
	~~Formaldehyde~~	~~CH_2O~~	~~Hydrocarbons (Aldehydes)~~
	~~Hydrogen Bromide~~	~~HBr~~	~~Hydrogen Halides~~
	~~Hydrogen Chloride~~	~~HCl~~	~~Hydrogen Halides~~
	~~Hydrogen Fluoride~~	~~HF~~	~~Hydrogen Halides~~
	~~Ammonia~~	~~NH_3~~	~~Nitrogen Containing~~
	~~Hydrogen Cyanide~~	~~HCN~~	~~Nitrogen Containing~~
# - This table was modified to reflect the gases measured during testing.			

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

Table 7 - Gas generation periods	
Time	**Condition**
00:24:47 - 03:00:00	Pre-Flaming
External Flaming of Gas	
Condition	**Duration (hh:mm:ss)**
External Flaming of Vent Gases:	No flaming observed

Table 8 – Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	Gas Type	During Pre-flaming (L)	During Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	435.21	No flaming	0.05
Carbon Dioxide	Carbon Containing	352.99	No flaming	0.64
Carbon Monoxide	Carbon Containing	134.14	No flaming	0.07
Hydrogen	Hydrogen	422.97	No flaming	4.10

Table 9 – Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR (kW)	No flaming observed	Maximum SRR (m^2/s)	2.29
--	--	Total Smoke Released (m^2)	707.75

Table 10 – Module Weight During Test, kg	
Before Test:	408.0
After Test:	403.4
Weight Loss:	4.6

Table 11 – Other Observations during module test		
	Observed, Yes/No	Location
Flying debris	No	Not Applicable
Explosive discharge of gas	No	Not Applicable
Sparks or electrical arcs	No	Not Applicable

	TABLE: Critical components information				
Object / Part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Lithium-ion Battery Module. EP096636PFB1					
Cells	LG Energy Solution, LTD.	JF2	3.20 Vdc, 159.2 Ah	UL 1973	RU (MH63736)
Case (Front Plate & Rear Plate & Top Plate)	-	-	Steel, Thickness: Min 1.0 mm	-	-
Case (Bottom Plate)	-	-	Aluminium, Thickness: Min 1.0 mm	-	-
Case (Side Plate)	-	-	Aluminium, Thickness: Min 3.5 mm	-	-
Case (Front cover)	NINGBO LG YONGXING CHEMICAL CO LTD	LUPOY EF1006F	Polycarbonate (PC), Thickness: Min 2.5mm, Flammability Rating: 5VA	UL 746, UL 94	RU (E203955)
Busbar	-	C1100	Min thickness: 2mm	-	-

List of test equipment used:

A completed list of used test equipment shall be provided in the Test Reports when a Customer's Testing Facility has been used.

Clause	Measurement / testing	Testing / measuring equipment / material used, (Equipment ID)	Range used	Last Calibration date	Calibration due date
--	Measurement	Cycler	Voltage: 1.9985 Vdc to 299.9850 Vdc / Current: 399.9852 A	2024-03-05	2025-03-04
--	Measurement	Humidity Meter	Humidity: 44.2 %RH to 62.3 %RH	2024-01-02	2025-01-01
--	Measurement	Multimeter	Voltage: 19.99 Vdc to 199.92 Vdc	2024-07-25	2025-07-24
--	Measurement & Testing	Data Acquisition	Temperature: - 0.5 °C to 598.0 °C	2024-02-03	2025-02-02
--	Measurement	Weighing Scale	10 to 1000 kg	2024-09-25	2024-09-24

Attachment A: Module Conditioning (Charge/discharge) Profiles - (*Pages **16** through **16***)

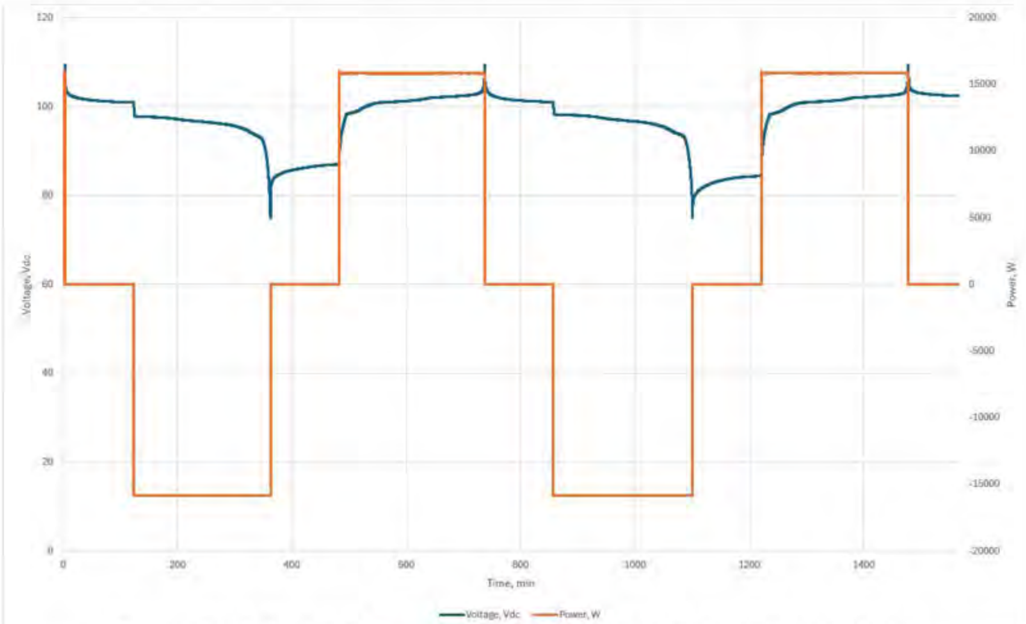


Figure A1. 2 Cycles of Charging and Discharging on the initiating Module

Attachment B: Module Construction Photos - (Pages ***17*** through ***17***)

Front **Side**

Figure B1. Overview of Module

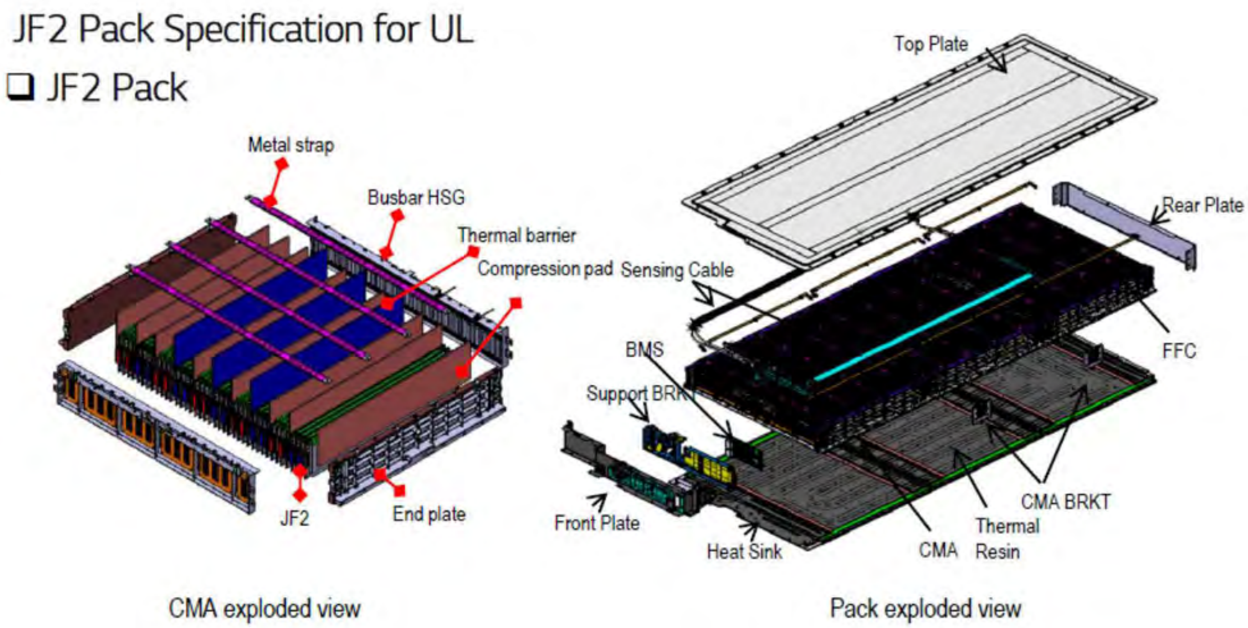
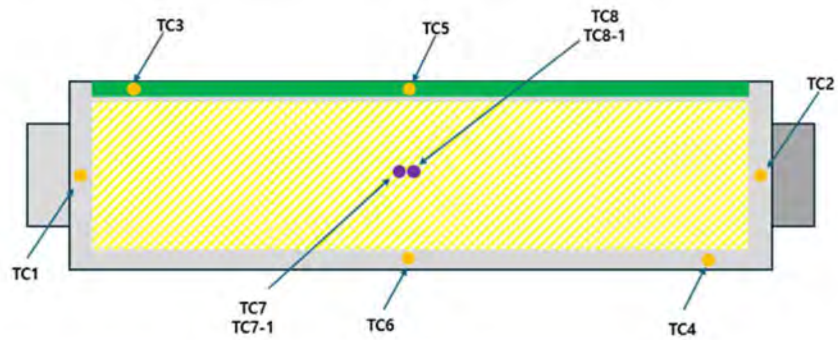


Figure B2. Exploded view of [1]Module and CMA

[1] A module has a total of three of Cell Module Assembly which has a total of forty cells.

Attachment C: Module Instrumentation Photos - (*Pages **18** through **20***)



TC #	TC Location
TC1	Positive (+) Terrace
TC2	Negative (-) Terrace
TC3	Positive (+) Cell Body, serves to report venting and thermal runaway temperature
TC4	Negative (-) Cell Body, serves to report venting and thermal runaway temperature
TC5	Cell Side
TC6	Cell Side
TC7	Center 1, Under heater, Heater Control
TC7-1	Opposite cell surface, Center 1, under heater, heater control
TC8	Center 2, Under heater, Heater Control Back up
TC8-1	Opposite cell surface, Center 2, under heater, heater control

Figure C1. Initiating cell instrumentation

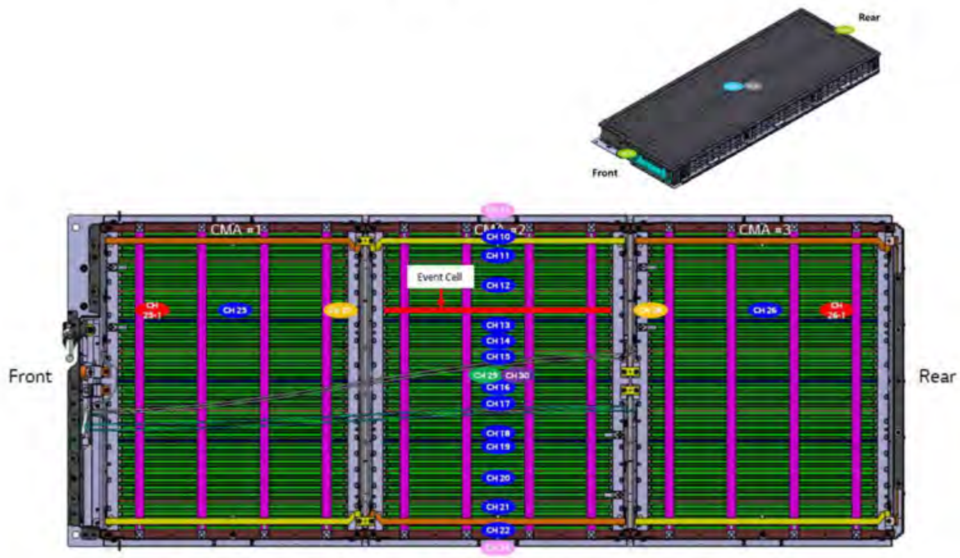
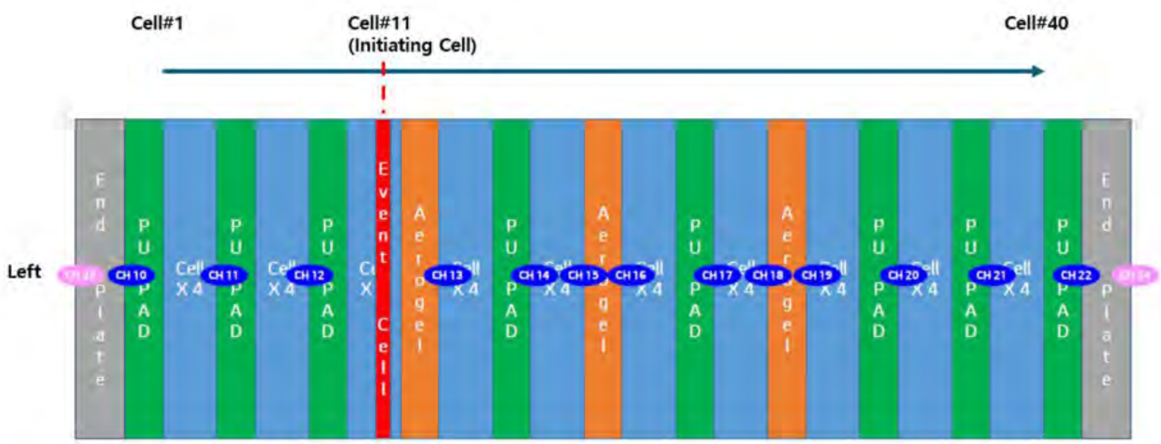


Figure C2. [2]Module cell and components instrumentation



CH#	Description of Thermocouple Location	CH#	Description of Thermocouple Location
CH10	Pad right next to Cell#1	CH21	Cell#37
CH11	Cell#4	CH22	Pad right next to Cell#40
CH12	Cell#8	CH23	Left side of CMA#2
CH13	Cell#13	CH24	Right side of CMA#2
CH14	Cell#17	CH25	Center of Cell#11 in CMA#1
CH15	Cell#20	CH25-1	Body of Cell#11 in CMA#1
CH16	Cell#21	CH26	Center of Cell#11 in CMA#3
CH17	Cell#25	CH26-1	Body of Cell#11 in CMA#3
CH18	Cell#28	CH27	Mica sheet between CMA#1 and CMA#2
CH19	Cell#29	CH28	Mica sheet between CMA#2 and CMA#3
CH20	Cell#33		

Figure C3. Channel of Thermocouples instrumentation on [3]CMA#2 in the initiating module

[2] One module has a total of three of CMA (i.e., Cell Module Assembly) in which there are a total of 40 cells. Please refer to Figure C3 for further details.

[3] Four cells compose one group, and one CMA has a total of ten groups.

CH#	Description of Thermocouple Location
CH31	Right above the initiating cell
CH32	Front
CH33	Rear
CH34	Center of Top Cover

Figure C4. Channel of Thermocouples instrumentation on exterior of the module

Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing - (*Pages **21** through **22***)

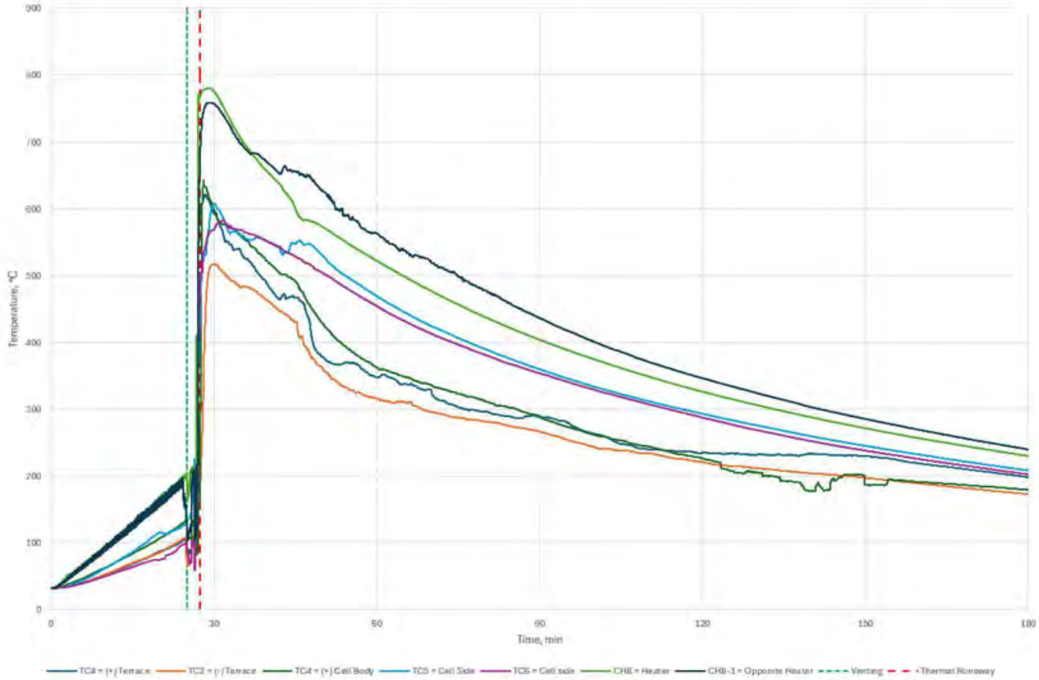


Figure D1. [4]Thermocouples on Initiating Cell

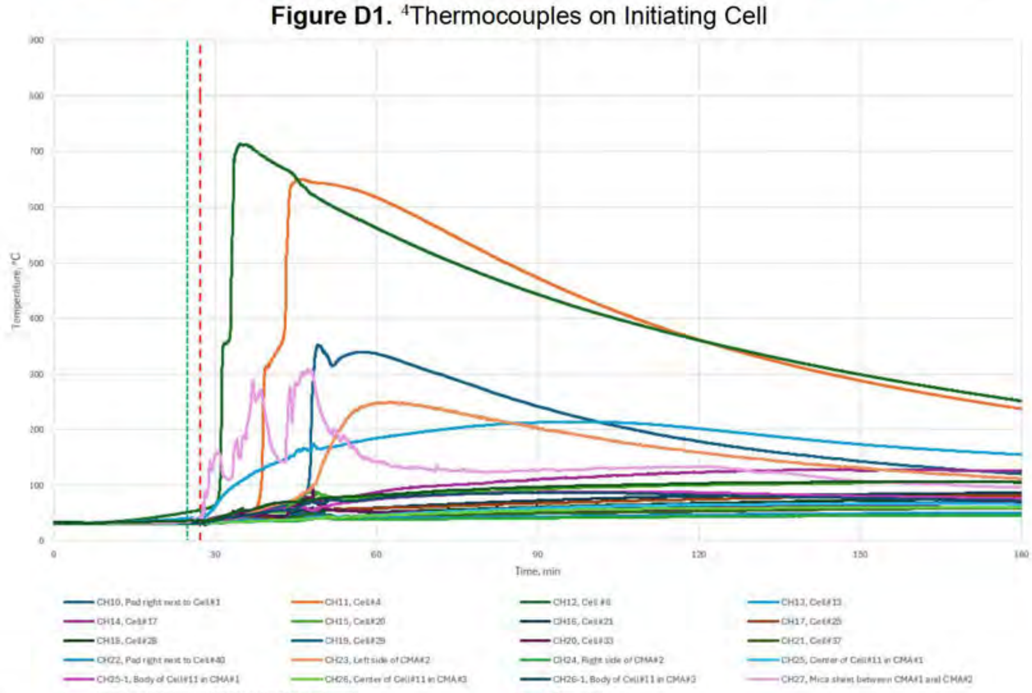


Figure D2. Channel of Thermocouples internal of Module excluding the initiating Cell (Cell#11)

---

4 TC3 was malfunctioned.

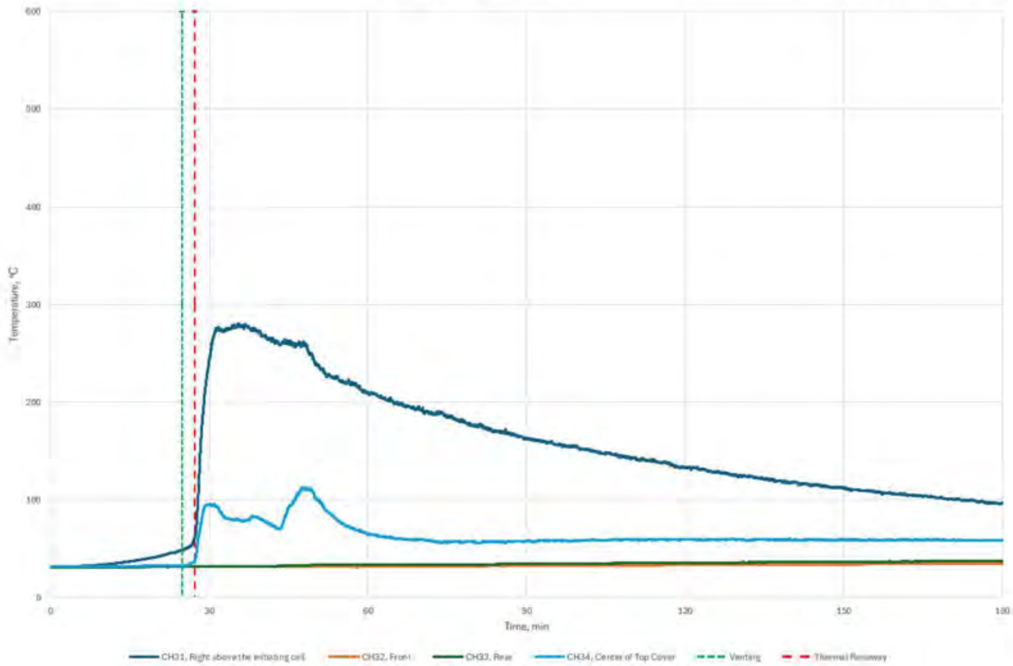
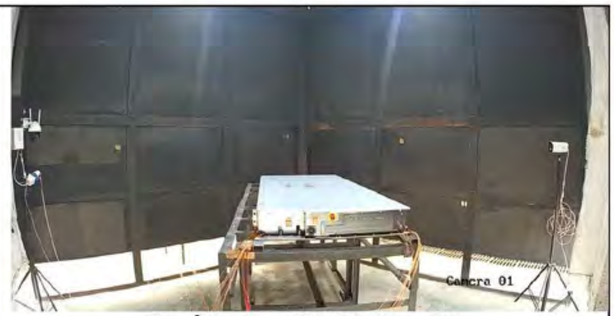
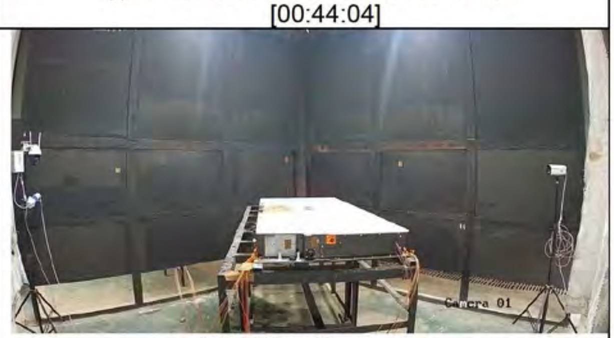


Figure D3. Channel of Thermocouples external of Module

Attachment E: Module Testing Photos - (*Pages **23** through **23***)

 (a) Test Start [00:00:00]	 (b) [5]Venting [00:24:45 ~ 47]
 (c) First Gas from the module [00:25:54]	 (d) Thermal Runaway (Initiating Cell#11) [00:27:14]
 (e) On-going of Thermal Runaway Propagation [00:37:43]	 (f) Maximum Smoke Release Rate [00:44:04]
 (g) Decreasing of Gas out of the module [00:70:00]	 (h) Video Stopped [02:45:00]

[5] There was no visual phenomenon. However, there was a clear sound from the module.

Attachment F: Module Gas Flow Rate and Heat Release Profiles - (*Pages **24** through **25***)

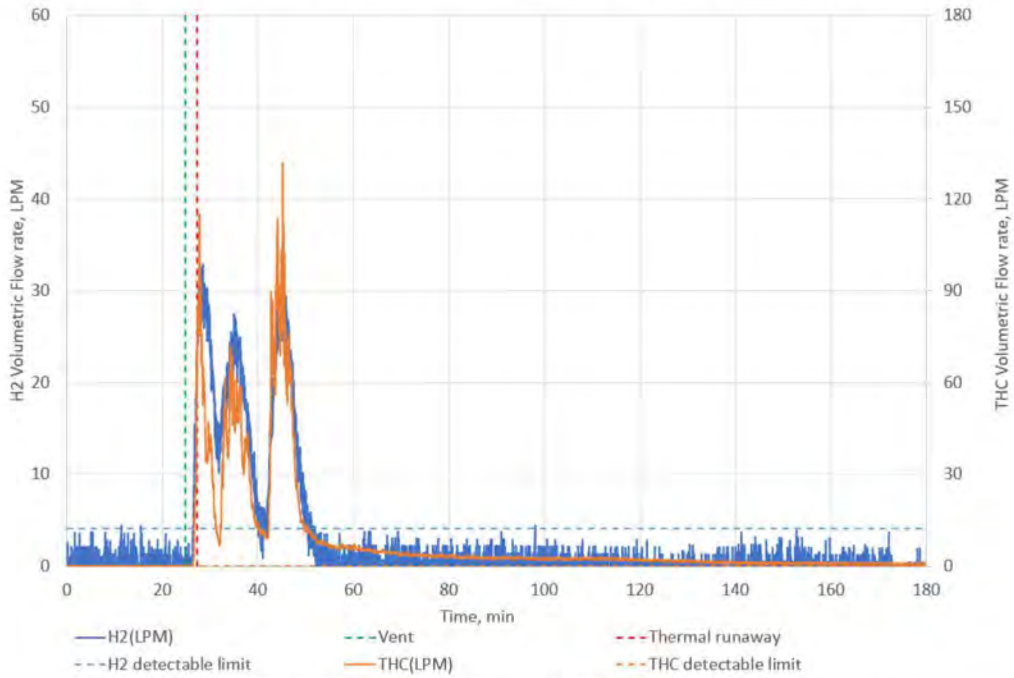


Figure F1. Volumetric flow rate of gases (Total Hydrocarbon and Hydrogen)

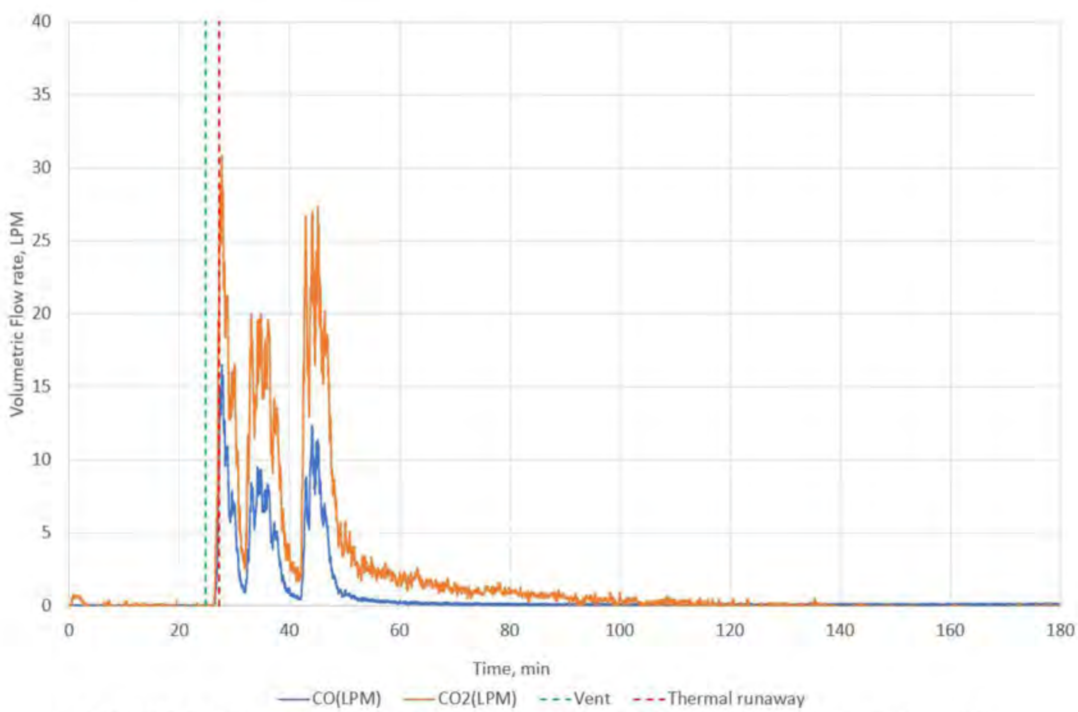


Figure F2. Volumetric flow rate of gases (Carbon Monoxide and Carbon Dioxide)

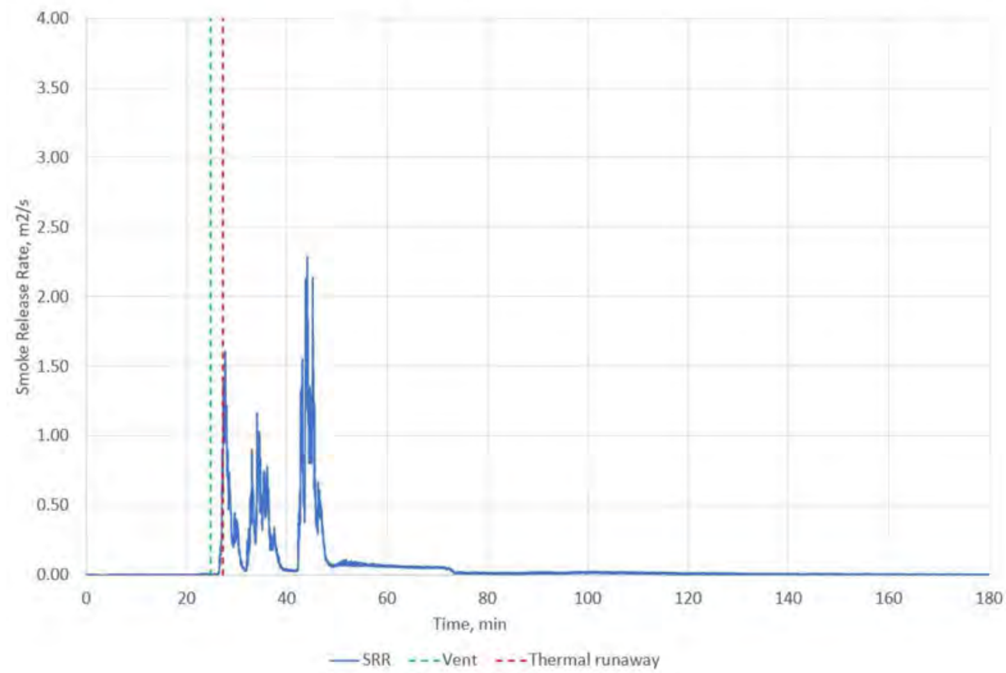


Figure F3. Smoke Release Rate

Attachment G: Certification Requirement Decision - (*Pages **26** through **27***)

CRD dated 2020-01-10 regarding the omission of FTIR provided below for reference.

UNDERWRITERS LABORATORIES INC. CERTIFICATION REQUIREMENT DECISION

This Certification Requirement Decision is prepared by UL LLC. It is normative for the applicable UL Product Certification Program(s); however, it is currently not part of the UL Standard(s) referenced below.

Product Category (CCN): AACD
Standard Number: UL 9540A
Standard Title: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Edition Date: November 12, 2019
Edition Number: 4
Section / Paragraph Reference: 8.12, 8.13, 9.24, 9.25, 10.3.13
Subject: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test.

DECISION:

8.2.1~~3~~2 The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.

8.2.1~~2~~3 The hydrocarbon components of the ~~V~~vent gas composition may additionally ~~shall~~ be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or an equivalent gas analyzer~~,~~. ~~and v~~Velocity and temperature measurements respectively shall be obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.

9.2.24 The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct as outlined in 8.2.10. The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor. ~~Gas composition shall be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), or equivalent gas analyzer.~~ Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.

9.2.25 The hydrocarbon content of the vent gas ~~shall~~ may additionally ~~also~~ be measured using ~~flame ionization detection.~~ a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), or equivalent gas analyzer

10.3.13 The composition of BESS unit vent gases shall be measured as outlined in Section 9.2.24. The hydrocarbon content may additionally be measured as outlined in accordance with 9.2.25 ~~using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), total hydrocarbon analyzer, and hydrogen analyzer~~. The gas composition sampling port shall be located in the ceiling jet, 25-mm (1-in) below the ceiling

RATIONALE FOR DECISION:

In the 4th edition of UL 9540A, there is redundancy in the two measurement methodologies used to characterize the volume of flammable gas released during module and unit level testing (Flame Ionization Detection (FID) and Fourier Transform Infrared Spectroscopy (FTIR)). Both FTIR and FID were developed as required measurements for module and unit level testing in the first three editions of UL 9540A before data existed that enabled an understanding of the typical compositions of battery gas. Both FID and FTIR were specified as requirements because it was not clear that FID alone would provide an adequate characterization of all flammable gases released by batteries in thermal runaway. Therefore, FTIR was first intended to provide a means to quantify non-hydrocarbon flammable gases as well as to serve as a backup for FID measurement. FTIR, to a lesser degree, was also identified as a potential backup or improvement for CO and CO_2. Experience has demonstrated that an improvement to CO and CO_2 measurement is not necessary and a backup to non-dispersive infrared spectroscopy (NDIR) measurement has not been needed. Therefore, the FTIR will remain in the standard but as an optional additional measurement method.

In addition, hydrogen is measured with a hydrogen specific sensor, because neither FID or FTIR are capable of measuring hydrogen.

The list of equipment in Table 1 demonstrates overlap in the methodologies used for gas measurement.

Table 1 – Gas measurement equipment for fire and explosion hazards

Gas Hazard	Measurement Equipment
Hydrocarbons	1. Total unburned hydrocarbons by flame ionization detector (FID) 2. Individual components by Fourier Transform infrared spectrometry (FTIR)
Carbon monoxide (CO), Carbon dioxide (CO_2)	1. Individual components by non-dispersive infrared spectrometry (NDIR) 2. Individual components by FTIR
Hydrogen	1. Hydrogen sensor

UNIT TEST REPORT
UL 9540A
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)

Project Number................................:	**4791516927**
Date of issue ....:	**2024-12-26**
Total number of pages...................:	**63**
UL Report Office ....:	**UL SOLUTIONS, KOREA**
Applicant's name...........................:	LG ENERGY SOLUTION, LTD.
Address ....:	188, MUNJI-RO, YUSEONG-GU DAEJEON, 34122 REPUBLIC OF KOREA
Test specification:	4th Edition, Section 9, November 12, 2019
Standard...:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure ....:	9.1 – 9.8
Non-standard test method ....:	N/A

General disclaimer:

The test results presented in this report relate only to the sample tested in the test configuration noted on the list of the attachments.

UL LLC did not select the sample(s), determine whether the sample(s) was representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation or identification of component materials used in the test sample(s).

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Cell level information	
Cells in Module:	
•Manufacturer Name	LG Energy Solution, Ltd.
•Part Number	JF2
•Chemistry	Lithium Iron Phosphate
•Format	Pouch
Ratings (Vdc, Ah) :	3.2 Vdc, 159.2 Ah
Cell certified? :	Yes
Standard the cell was certified to:	UL 1973, Annex E
Organization that certified the cell:	UL Solutions (UL File No.: MH63736)
Average cell surface temperature at gas venting, °C:	128.9
Average cell surface temperature at thermal runaway, °C:	209.6
Gas Volume:	64.0
Lower flammability limit (LFL), % volume in air at the ambient temperature:	7.4
Lower flammability limits (LFL), % volume in air at the venting temperature:	6.6
Burning velocity (S_u) cm/s:	85.6
Maximum pressure (P_{max}) psig:	98.9

Cell level Gas Composition:

Gas	Measured %
Hydrogen	59.3
Carbon monoxide	10.0
Carbon Dioxide	22.4
Methane	3.68
Ethane	0.53
Ethylene	2.53
Acetylene	0.16
Propane	0.12
Propene (Propylene)	0.26
C4 Total	0.40
C5 Total	0.12
C6 Total	0.39
C7 Total	0.04
C8 Total	0.06
Benzene	0.09
Toluene	0.01
Xylene	0.01
Total	**100**

Module level Information	
Model No.. :	EP096636PFB1
Ratings (Vdc, Ah)............................ :	96.0 Vdc, 636.8 Ah
Module dimensions (X x Y x Z (mm))...................:	30S/4P
Module cell configuration (xS/yP) ......:	825.0 x 2085.0 x 145.0
Module weight (kgs)............................ :	Max 410 kg
Module enclosure material.................... :	Front plate & Rear plate: Steel, Min 1.0 mm Top plate: Steel, Min 1.0 mm Bottom plate: Aluminium, Min 1.5 mm Side Plate: Aluminium, Min 3.5 mm Front cover: Polycarbonate (PC), Min 2.5 mm
Was the module certified? ....:	No
Standard the module was certified to ....:	-
Organization that certified test item ....:	-
Number of initiating cells failed to achieve propagation.	1
Thermal Runaway Propagation:	Propagation observed
External Flaming:	No external flaming
Location(s) of Flame Venting:	N/A
Flying Debris:	N/A
Re-ignitions:	N/A
Test Maximum Smoke Release Rate (m^2/s)	2.29
Test Total Smoke Released: (m^2)	707.75
Test Peak Chemical Heat Release Rate: (kW):	No flaming observed

Module level test Gas Composition & Volume for Each Compound (Pre-flaming and After flame) :

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate(LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	435.21	No flaming observed	0.05
Carbon Dioxide	Carbon Containing	352.99	No flaming observed	0.64
Carbon Monoxide	Carbon Containing	134.14	No flaming observed	0.07
Hydrogen	Hydrogen	422.97	No flaming observed	4.10

Unit level Information	
Model No. :	NR27N414L_P15190NB3
Ratings (Vdc, Ah)............................ :	1344.0 Vdc, 636.8Ah
BESS dimensions (W x D x H (mm))..................:	1,070 X 2,117 X 2,678
BESS module configuration	14S1P
Number of modules in BESS	14
Module cell configuration (xS/yP) ......:	30S4P
Number of cells in module.:	120
BESS weight (kgs)............................ :	6,955
BESS enclosure material.................... :	Steel
BESS Intended Installation: **Non Residential:** outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted, roof top, open garage **Residential:** Outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted	Non-Residential indoor floor mounted
Residential Indoor Use: Smallest volume room installations specified.	N/A
Original Equipment Manufacturer (OEM):	LG Energy Solution, Ltd.
Branding Manufacturer (if not OEM):	N/A
Was the unit certified? ....:	No
Standard the unit was certified to ....:	N/A
Organization that certified the unit ....:	N/A
Cell failure test method performed (summary of method and test clause): ☒ External heating using thin film with 4°C to 7°C thermal ramp. ☐ Nail Penetration ☐ Overcharge ☐ External short circuit (***X*** Ω *external resistance*) ☐ Others	
Description of method used to fail cells if other than external thin film heater with thermal ramp, : N/A	
Description of components employed within the BESS unit that serve to suppress propagation (fire protection features) Suppression against propagation within the BESS unit is implemented at each module level with aerogel pads of three. Each module consists of a total of three CMAs (i.e., Cell Module Assembly) and, each CMA has a total 40 cells. For suppression against propagation from thermal runaway, there are three aerogel pads in each CMA, and Mica sheet is between CMA and CMA. Please refer to Attachment C in this report.	
Deviation from the module level test **N/A**	
Number of initiating cell(s)	1

Thermal Runaway Propagation:	Thermal runaway propagated in the initiating module
External Flaming from BESS:	No
Location(s) of Flame Venting:	N/A
Maximum Target BESS Temperature, °C	40.8 (Target Unit 1)
Maximum Wall Surface Temperature, °C	30.8 (Rear Wall)
Peak Chemical Heat Release Rate, kW	No flaming observed during the test
Peak Convective Heat Release Rate, kW	No flaming observed during the test
Maximum Smoke Release Rate, m^2/s	1.84
Maximum Heat Flux on Target Modules, kW/m^2	0.58 (Target Unit 1)
Maximum Heat Flux of Egress Path, kW/m^2	0.02
Flying Debris:	None
Re-ignitions:	N/A

Gas Analysis:

☒ Flame ionization detection (FID)

☒ Non-Dispersive Infrared Spectrometer (NDIR)

☐ Fourier-Transform infrared Spectrometer

☒ Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)

☒ White light source with photo detector (smoke release rate)

Summary of Unit level test Gas Analysis Data:

Unit level Gas Composition & Volume for Each Compound (Pre-flaming and After flame):

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	242.98	No flaming observed	0.36
Carbon Monoxide	Carbon Containing	91.61	No flaming observed	0.26
Carbon Dioxide	Carbon Containing	231.85	No flaming observed	1.22
Hydrogen	Hydrogen	258.28	No flaming observed	15.35

Summary of BESS Unit Test Results
Performance Criteria in accordance with Table 9.1 for Indoor Floor Mounted non-residential unit
[X] Flaming outside the initiating BESS unit was not observed; **[X]** Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit did not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8; **[N/A]** ~~For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces did not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;~~ **[X]** Explosion hazards were not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and **[X]** Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.
Necessity for an Installation level test
~~[ ] The performance criteria of the unit level test as indicated in Table 9.1 of UL 9540A 4th edition has not been met, therefore an installation level testing in accordance with UL 9540A will need to be conducted on the representative the installation with this unit installed.~~ **[X]** The performance criteria of the unit level tests as indicated in Table 9.1 of UL 9540A 4th edition has been met, therefore an installation level testing in accordance with UL 9540A need not be conducted.
Testing Laboratory Information
Testing Laboratory and testing location(s):

Testing Laboratory:	UL Solutions	
Testing location/ address ....:	SOUTH CHINA TESTING AND CERTIFICATION CO LTD / Li Kou Section Guangshan Road, Zengjiang Street, Zengche District,Guangzhou, Guangdong, CN	
Tested by (name, signature)........................:	Ali, Lin	
Project Handler (name, signature)..............:	Donghyun Kim	Donghyun Kim
Reviewer (name, signature) ....:	Benjamin Liu	Benjamin Liu

List of Attachments (including a total number of pages in each attachment):
Attachment A: Sample Charging, OCV and SOC Measurement Profiles - (*Pages **27** through **40***)
Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams - (*Pages **41** through **41***)
Attachment C: BESS and Equipment Instrumentation and Test Installation Layout Photos/Diagrams - (*Pages **42** through **51***)
Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. - (*Pages **52** through **56***)
Attachment E: BESS Unit Testing and Post Testing Photos - (*Pages **57** through **59***)
Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles - (*Pages **60** through **61***)
Attachment G: Certification Requirement Decision - (*Pages **62** through **63***)

Photo(s) of BESS unit:

Test Item Charge/Discharge Specifications:	
• **Charge power, kW/ ~~current, A~~:**	213.962
• **Standard Full charge voltage, Vdc:**	1499.4
• **Charge temperature range, °C:**	0.0 to 40.0
• **End of charge current, A:**	N/A
• **Discharge power, kW/ ~~current, A~~:**	213.962
• **End of discharge voltage, Vdc:**	1134.0
• **Discharge temperature range, °C:**	0.0 to 40.0

Test item particulars ....:	
Possible test case verdicts:	
- test case does not apply to the test object...........:	N/A
- test object does meet the requirement ....:	P (Pass)
- test object does not meet the requirement...........:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification......:	M(Modification)
Testing..:	
Date of receipt of test item ....:	2024-10-15
Date (s) of performance of tests...........................:	2024-10-24

General remarks:

"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.

Throughout this report a point is used as the decimal separator.

Manufacturer's Declaration of samples submitted for test:

The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided ...:	☐ **Yes** ☒ **Not applicable**
Name and address of factory (ies).......................:	NANJING ZHONGSHAN ELECTRONICS Co., Ltd. No 18 Yihu Road, Lishui Economic Development Zone, Lishui County, Nanjing, Jiangsu Province, China 211200

General product information and other remarks:

The battery energy storage unit, Model NR27N414L_P15190NB3 is composed of 14 modules (model No.: EP096636PFB1) rated 96.0 Vdc, 636.8 Ah in series and 1 BPU (Battery Protection Unit) that is an electrical part. The module has Lithium Iron Phosphate cells with 30S4P cell configuration. The cell model is JF2 rated 3.20 Vdc and 159.2 Ah manufactured by LG Energy Solution. The basic electrical ratings of the unit are 636.8 Ah (nominal capacity) and 1344.0 Vdc (nominal voltage).

5.0	CONSTRUCTION		Verdict
5.3	**Battery energy storage system unit Construction**		—
5.3.1, 5.3.2	Construction information	See Test Item Description at the beginning of this report	—
5.3.2	General layout of BESS unit contents	See Attachment B	—
5.3.3	Details of integral fire suppression system	Unit does not have an integral fire suppression system.	N/A
5.3.1	BESS certified to UL 9540	No	C
	Organization that certified BESS:	N/A	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**	--	--
9.1	**Sample and test configuration**	--	--
9.1.1	The unit level test conducted with BESS units installed as described in the manufacturer's instructions.	See Attachment C for test installations. Installation type: Non-residential, Indoor floor mounted	C
9.1.2	The unit level test required one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation.	See Attachment C for test installations.	C
	Tests conducted for indoor floor mounted installations are representative of both indoor floor mounted and outdoor ground mounted installations.	The BESS unit is intended for indoor use.	N/A
	Tests conducted indoors with fire propagation hazards and separation distances between initiating and target units representative of the installation.	See Attachment C. The distance between initiating unit and target units is 0 mm.	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	Testing conducted outdoors for outdoor only installations with following in place: a) Wind screens with wind speed of ≤ 12 mph; b) Temperature range is 10°C to 40°C (50°F to 104°F); c) Humidity is < 90% RH; d) Sufficient light to observe the testing; e) There is no precipitation; f) There is control of vegetation and combustibles in the test area; and g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area.	The BESS unit is intended for indoor use.	N/A
9.1.3	Testing to determine fire characterization was done at the battery system level rather than a complete BESS	Testing was done at the battery rack system level.	C
9.1.4	The initiating BESS contained components representative of a BESS unit in a complete installation.	Complied.	C
	Combustible components that interconnect the initiating and target BESS units was included.	There is no combustible components interconnected between Target Units and the Initiating Unit.	C
9.1.5	Target BESS units include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components.	Complied.	C
9.1.6	The initiating BESS was at the maximum operating state of charge (MOSOC),	See Attachment A.	C
	After charging and prior to testing, the initiating BESS was at rest for a maximum period of 8 hours at room ambient.	See Table 2.	C
9.1.7	The BESS unit included an integral fire suppression system.	No integral fire suppression system is included in the BESS unit.	N/A
9.1.8	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.	BMS was not operated during the test.	C
	Included a fire suppression control in accordance with UL 864 that is external to the BESS.	No fire suppression control was employed.	N/A
9.2	**Test method – Indoor floor mounted BESS units**	--	--
9.2.1	Test room ambient temperature within 10°C (50°F) to 32°C (90°F).	See Table 2.	C

Clause	Requirement + Test	Result - Remark	Verdict
9.2.2	Access door(s) or panels on the initiating BESS unit and adjacent target BESS units were closed, latched and locked duration of the test.	The BESS unit has no doors or latches.	N/A
9.2.3	The initiating BESS unit was positioned adjacent to two instrumented wall sections.	See Attachment C.	C
9.2.4	Instrumented wall sections extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of target BESS units.	Complied.	C
9.2.5	Instrumented wall sections were at least 0.61-m (2-ft) taller than the BESS unit height, but not less than 3.66 m (12 ft) in height above the bottom surface of the unit.	Complied.	C
9.2.6	The surface of the instrumented wall sections were covered with 16-mm (5/8-in) gypsum wall board and painted flat black.	See Attachment C.	C
9.2.7	The initiating BESS unit was centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.	Complied.	C
9.2.8	The light transmission in the calorimeter's exhaust duct was measured using a white light source and photo detector. The smoke release rate was calculated.	See Table 11. See Attachment F.	C
9.2.9	The chemical and convective heat release rates were measured for the duration of the test.	No flaming was observed during the test.	C
9.2.10	The heat release rate measurement system was calibrated using an atomized heptane diffusion burner. The calibration was performed using flows of 3.8, 7.6, 11.4 and 15.2 L/min (1, 2, 3 and 4 gpm) of heptane.		N/A
9.2.11	The chemical heat release rate was measured using the following equipment: • Paramagnetic oxygen analyser • Non-dispersive infrared carbon dioxide and carbon monoxide analyser • Velocity probe • Type K thermocouple		N/A
9.2.12	The chemical heat release rate at each of the flows was calculated.		N/A
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls was representative of the intended installation.	See Attachment C.	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
9.2.14	Separation distances were specified by the manufacturer for distance between: a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units.	See Attachment C.	C
9.2.15	Wall surface temperature measurements were collected	See Table 6. See Attachment D.	C
	The intended installation is composed completely of non-combustible construction.	Complied.	C
9.2.16	Wall surface temperatures were measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller, Type-K exposed junction thermocouples.	Complied.	C
	The thermocouples for measuring the temperature on wall surfaces were horizontally positioned in the wall locations to receive greatest thermal exposure from the initiating BESS unit.	Complied.	C
9.2.17	Thermocouples were secured to gypsum surfaces and the thermocouple tip was depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement.	Complied.	C
9.2.18	Heat flux was measured with at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall: a) Both are collinear with the vertical thermocouple array; b) One is positioned to receive the greatest heat from the initiating module; and c) One is positioned to receive the greatest heat flux during potential propagation within the initiating BESS unit.	See Attachment C.	C

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Clause	Requirement + Test	Result - Remark	Verdict
9.2.19	Heat flux was measured with 2 water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS units facing initiating BESS unit: a) One is positioned at the elevation estimated to receive the greatest heat flux from the initiating module; and b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to initiating BESS.	Only one heat flux gauge was installed in each target unit at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module. No secondary heat flux was installed because: • the distance between each target unit and the initiating unit is 0 mm; and based upon engineering discretion, flaming was expected near the initiating module, and the area that was assumed would experience the greatest surface heat flux during thermal runaway in the initiating BESS was right next to the initiating module.	C
9.2.20	Heat flux was measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge positioned in the center of the accessible means of egress.	Complied.	C
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples were installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module.	See Attachment C	C
	Each non-initiating module enclosure within the initiating BESS unit was instrumented with at least one No. 24-gauge or smaller Type-K thermocouple(s) within non-initiating modules.	See Attachment C.	C
	Additional thermocouples were placed to account for convoluted geometries.	No convoluted geometries were included	N/A
9.2.22	For residential use, the DUT was covered with a single layer of cheese cloth ignition indicator. The cheesecloth was untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in^2) area.	The BESS unit is not for residential unit.	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
9.2.23	An internal fire condition in accordance with the module level test was created within a single module in the initiating BESS unit: a) The position selected to present the greatest thermal exposure to adjacent modules; and b) The setup was the same as that used to initiate and propagate thermal runaway within the module level test.	See Attachment C.	C
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases was measured within the calorimeter's exhaust duct. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.	Complied.	C
	Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.	Complied.	C
	The hydrocarbon content of the vent gas may also be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer.	FTIR analysis was not used in accordance with the Certification Requirement Decision: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test. FTIR was considered redundant to the other gas measurement methods used. See Attachment G.	N/A
9.2.25	The hydrocarbon content of the vent gas was measured using flame ionization detection.	See Tables 8, 9 and 10	C
9.7	**Unit level test report**	--	--
9.7.1	Installation type tested:	Indoor floor mounted non-residential use BESS	C
9.7.2	Testing is intended to represent more than one installation type.	See Test Item Description in beginning of this report.	C
9.7.3	a. Unit manufacturer name and model number (and whether UL 9540 compliant);	Complied.	C
	b. Number of modules in the initiating BESS unit	Complied.	C

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Clause	Requirement + Test	Result - Remark	Verdict
	c. BESS construction features;	See Attachment C See Critical Components Table ☐ See Also "Description of components employed within the module that impact propagation (fire protection features)" at the beginning of this report.	C
	d. Fire protection features/ detection/ suppression systems within unit	No fire protection features, detections or suppression systems utilized.	N/A
	e. Module voltages corresponding to the tested SOC;	See Attachment A.	C
	f. Thermal runaway initiation method used;	External heater was used for forcing a cell into thermal runaway.	C
	g. Location of the initiating module within the BESS unit;	See Attachment C.	C
	h. Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	See Attachment C.	C
	i. Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	No flaming observed.	C
	j. Chemical and convective heat release rate versus time data;	See Table 11.	C
	k. Separation distances from the initiating BESS unit to target walls	See Attachment C.	C
	l. Separation distances from the initiating BESS unit to target BESS units	See Attachment C.	C
	m. The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	See Tables 5 and 6.	C
	n. The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;	See Table 6.	C
	o) The maximum incident heat flux on target wall surfaces and target BESS units;	See Table 7.	C
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;	See Table 7.	C
	q. Flammable gas generation and composition data;	See Attachment F. See Tables 8, 9, and 10.	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

	r. Peak smoke release rate and total smoke release data.	See Table 11. See Attachment F.	C
	s. Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	No integral fire protection system	N/A
	t. Observation(s) of flying debris or explosive discharge of gases;	No flying debris or explosive discharge of gases	C
	u. Observation of re-ignition(s) from thermal runaway events	No re-ignition from thermal runaway events	C
	v. Observation(s) of sparks, electrical arcs, or other electrical events;	No sparks, electrical arc or other electrical events	C
	w. Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits;	See Attachment E.	C
	x. Video of the test.	Videos provided to the customer.	C
9.8	**Performance at Unit level testing**	–	–
9.8.1	Installation level testing in Section 10 was not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.	Pass.	P
Non-Residential Installations – Indoor floor mounted:			
	a) Flaming outside the initiating BESS unit is not observed;	No flaming observed.	P
	b) Surface temperatures of modules within target BESS units do not exceed the cell venting temperature;	The maximum temperature on the surface of modules within target BESS units was 40.8 °C, and the vent temperature at the cell level was 128.9 °C. See Table 5 and Attachment D.	P
	c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) rise above ambient;	The maximum surface temperature measurement on wall surfaces was 30.8 °C. See Table 6 and Attachment D.	P
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases;	Explosion hazard was not observed during the test.	P

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	e) Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.	Heat flux in the center of the accessible means of egress was 0.02 kW/m^2 See Table 7.	P

Table 1 – Specified Module charging and discharging parameters			
Charging:		**Discharging:**	
Power (CP), W / ~~Current (CC), A~~	15,283	Power (CP), W / ~~Current (CC), A~~	15,283
Standard full Charge Voltage, Vdc	109.5	End of discharge voltage, Vdc	75.0
End of charge current, A	N/A	Discharging Test Ambient, °C	0 ~ 40
Charging Test Ambient, °C	0 ~ 40		
Refer to Attachment A for charge/discharge profiles.			

Table 2 - Test Initiation Details	
Test Date	2024-10-24
Test Start Time (HH:MM:SS)	AM 09:51:00
Initial Lab Temperature, °C	22.5
Initial Relative Humidity % RH	47.5
Module OCV at Start of Test, Vdc	Please refer to Table 12 on this report.

Table 3 – Approximate time of thermal runaway propagation through module			
Locations (Cell #)	**Event**	**Time**	**Temperature of the cell, °C**
Cell 11	Vent	00:29:53	136.22
Cell 11	Thermal Runaway	00:32:59	146.63

Table 4 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	Test was started; the initiating cell was heated at the rate from 4 °C/min to 7 °C/min. TC7 & TC7-1 were used to control the heater.
00:29:53	Initiating Cell Vent	Initiating cell (Cell 11) vent; Visual indication of vent was not observed but temperature dip was observed in data of the initiating cell. The measured temperature on the initiating cell is 136.2°C.
00:32:59	Initiating Cell Thermal Runaway	Initiating cell (Cell 11) went into thermal runaway; temperature rise through self-heating in an uncontrolled manner was observed. The power supply to the heaters was turned off at this point. The measured temperature from TC3 on the initiating cell was 146.63°C at the onset of thermal runaway.
00:34:09	Maximum Smoke Release Rate	Smoke Release Rate measured was 1.84 m^2/s.
00:35:47	Coolant spilled	Coolant was observed to spill out of its components retaining it.
00:35:59 ~ 00:55:59	Thermal Runaway Propagation	Cell-to-cell propagation was observed. Of the cells instrumented with thermocouples, only Cell #8(00:35:59), Cell #4 (0:45:18) and the pad right next to Cell#1 (00:55:19), entered thermal runaway based on the temperature data. Please refer to Figure C4 for the detailed information on the cell locations.
03:09:00	End of Video	Recording of the video was ended after three hours and nine minutes since beginning of the test. The samples were in the testing room overnight and all temperatures were confirmed that they were around ambient on next day.

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Clause	Requirement + Test	Result - Remark	Verdict

Table 5 - Maximum Temperatures in Target Units			
Cell vent temperature from cell test data, °C		128.9	
Target Unit 1		**Target Unit 2**	
Module Location No.	Temperature (°C)	Module Location No.	Temperature (°C)
Module 1	27.2	Module 1	26.9
Module 2	26.9	Module 2	26.6
Module 3	26.8	Module 3	26.4
Module 4	26.8	Module 4	26.4
Module 5	26.9	Module 5	26.4
Module 6	27.0	Module 6	26.5
Module 7	27.1	Module 7	26.7
Module 8	27.4	Module 8	26.7
Module 9	27.9	Module 9	26.7
Module 10	29.1	Module 10	26.9
Module 11	35.8	Module 11	27.2
Module 12	**40.8**	Module 12	27.1
Module 13	29.8	Module 13	27.1
Module 14	27.4	Module 14	26.8

Table 6 - Maximum Temperatures on Instrumented Wall					
Ambient Temperature: 22.5 °C					
UL 9540A performance criteria, Ambient + 97°C: [1]N/A					
Front Wall Temperature					
Height, mm (in)	Maximum Temperature (°C)	Height, mm (in)	Maximum Temperature (°C)	Height, mm (in)	Maximum Temperature (°C)
0 in.	26.6	48 in.	27.2	96 in.	27.1
6 in.	27.0	54 in.	27.2	102 in.	27.2
12 in.	27.1	60 in.	27.2	108 in.	27.2
18 in.	27.2	66 in.	27.3	114 in.	27.2
24 in.	27.2	72 in.	27.2	120 in.	27.4
30 in.	27.1	78 in.	27.1	126 in.	27.4
36 in.	27.1	84 in.	27.1	132 in.	27.3
42 in.	27.2	90 in.	27.1	138 in.	27.4
Rear Wall Temperature					
Height, mm (in)	Maximum Temperature (°C)	Height, mm (in)	Maximum Temperature (°C)	Height, mm (in)	Maximum Temperature (°C)
0 in.	26.7	54 in.	27.9	108 in.	27.0
6 in.	26.7	60 in.	27.5	114 in.	27.2
12 in.	26.9	66 in.	27.4	120 in.	27.3
18 in.	26.8	72 in.	27.0	126 in.	27.3
24 in.	26.8	78 in.	26.9	132 in.	27.4
30 in.	27.8	84 in.	27.0	138 in.	27.4
36 in.	**30.8**	90 in.	26.9	144 in.	27.5
42 in.	30.4	96 in.	26.9	150 in.	27.2
48 in.	28.7	102 in.	27.0		
Note: Temperatures are measured constantly and then averaged every 60-seconds					

[1] The intended installation is composed completely of non-combustible construction.

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

Table 7 – Heat Flux Measurements			
Summary of maximum heat flux in target units		Summary of maximum heat flux measured on instrumented wall	
Maximum Heat Flux, kW/m²			
Target Module No. 1:	0.58	Heat Flux Gauge No.	kW/m²
Target Module No. 2:	0.05	Rear wall (Bottom)	0.09
Egress path measurement (1,520 mm away from the front of the module)	0.02	Rear wall (Top)	0.11
--	--	measurement on Top of Front wall (3,040 mm away from the front of the module)	0.04
--	--	measurement on Bottom of Front wall (3,040 mm away from the front of the module)	0.02

Table 8 – Gases measured and measurement methods used in unit level testing			
Measurement Method	**Gases Measured**	**Chemical Formula**	**Gas Type**
Flame Ionization Detection (FID)	Total Hydrocarbons	-	Hydrocarbons
Solid-state Hydrogen Sensor	Hydrogen	H_2	--
Non-dispersive infrared spectroscopy (NDIR)	Carbon Dioxide	CO_2	Carbon Containing
	Carbon Monoxide	CO	Carbon Containing
~~[ ] Fourier Transform Infrared Spectrometer (FTIR)~~	~~Acetylene~~	$\cancel{C_2H_2}$	~~Hydrocarbons~~
	~~Ethylene~~	$\cancel{C_2H_4}$	~~Hydrocarbons~~
	~~Methane~~	$\cancel{CH_4}$	~~Hydrocarbons~~
	~~Methanol~~	$\cancel{CH_3OH}$	~~Hydrocarbons~~
	~~Propane~~	$\cancel{C_3H_8}$	~~Hydrocarbons~~
	~~Formaldehyde~~	$\cancel{CH_2O}$	~~Hydrocarbons (Aldehydes)~~
	~~Hydrogen Bromide~~	~~HBr~~	~~Hydrogen Halides~~
	~~Hydrogen Chloride~~	~~HCl~~	~~Hydrogen Halides~~
	~~Hydrogen Fluoride~~	~~HF~~	~~Hydrogen Halides~~
	~~Ammonia~~	$\cancel{NH_3}$	~~Nitrogen Containing~~
	~~Hydrogen Cyanide~~	~~HCN~~	~~Nitrogen Containing~~
# - This table was modified to reflect the gases measured during testing.			

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

Table 9 - Gas generation periods	
Time	**Condition**
00:29:53 – 2:00:00	Pre-Flaming
External Flaming of Gas	
Duration (hh:mm:ss)	**Condition**
No Flaming Observed	External Flaming of Vent Gases: No Flaming Observed

Table 10 – Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	**Gas Type**	**During Pre-flaming (L)**	**During Flaming (L)**	**Minimum detectable flow rate (LPM)**
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	242.98	No flaming observed	0.36
Carbon Monoxide	Carbon Containing	91.61	No flaming observed	0.26
Carbon Dioxide	Carbon Containing	231.85	No flaming observed	1.22
Hydrogen	Hydrogen	258.28	No flaming observed	15.35

Table 11 – Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR (kW)	No Flaming observed	Maximum SRR (m^2/s)	1.84
Peak Convective HRR, (kW)	No Flaming observed	Total Smoke Released (m^2)	515.98

Table 12 - Module OCV voltage measurement comparison before and after testing			
Module Location In Rack	OCV Prior to Test (V)	OCV Post Test (V)	Difference (V)
1	101.55	101.39	-0.12
2	100.37	100.25	-0.12
3	100.22	100.17	-0.05
4	100.32	100.22	-0.10
5	100.21	100.17	-0.04
6	100.32	100.22	-0.10
7	100.21	100.17	-0.04
8	100.46	100.33	-0.13
9	100.23	100.16	-0.07
10	100.31	100.21	-0.1
11	100.23	100.14	-0.07
12 (Initiating Module)	100.23	90.04	-10.19
13	100.21	100.16	-0.05
14	100.44	100.31	-0.13

Table 13 – Other Observations during Unit test			
	Observed, Yes/No	Comments/Location	
Flaming outside of Unit	No	Length of flame:	No flaming observed
Flying debris	No		
Explosive discharge of gas	No		
Sparks or electrical arcs	No		

Table 14 - Post Test Observations	
Thermal runaway behaviour	No Thermal runaway
Re-ignitions	No re-ignitions
Explosions	No explosions
Other Observations	No other observations

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

TABLE: Critical components information					
Object / Part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cells	LG Energy Solution, LTD.	JF2	Nominal Rating: 3.20 Vdc, 159.2 Ah	UL 1973	RU (MH63736)
Module	LG Energy Solution, LTD.	EP096636PFB1	Nominal Rating: 96.0 Vdc, 636.8 Ah	-	-
Battery Protection Unit	LG Energy Solution, LTD.	P15190NB3	-	-	-
Unit	LG Energy Solution, LTD.	NR27N414L_P15190NB3	Nominal Rating: 1344.0 Vdc, 636.8Ah	-	-
Rack Assembly	-	Open rack frame / Material. SPA-H	Min thickness 3.0 mm, 2,878 (H) x 1,978 (W) x 2,117 (D)	-	-
Power Cable	3Q WIRE & CABLE CO LTD	Style 3817	125°C, 3000 Vac AWG 4/0	UL 758 (AVLV2)	RU (E341104)
Module to Module Communication wiring	LS CABLE & SYSTEM LTD	Style 2464	80 °C, 300 Vac, AWG 22	UL 758 (AVLV2)	RU (E52853)
Module to BPU communication wiring	LS CABLE & SYSTEM LTD	Style 2464	80 °C, 300 Vac, AWG 22	UL 758 (AVLV2)	RU (E52853)
Coolant pipe Assy	LG Energy Solution, LTD.	-	Polyamide	UL94 UL746C	RU (E171666, E53898, E513123)
Coolant	Jiangsu Samyang Environmental Science Technology Co., Ltd.	SEV1-R3A-35	Ethylene glycol: 50 ~ 55 % EDI deionized water: 45 ~ 50% Additives: 1 ~ 5 %	-	-

Attachment A: Sample Charging, OCV and SOC Measurement Profiles - (*Pages **27** through **40***)

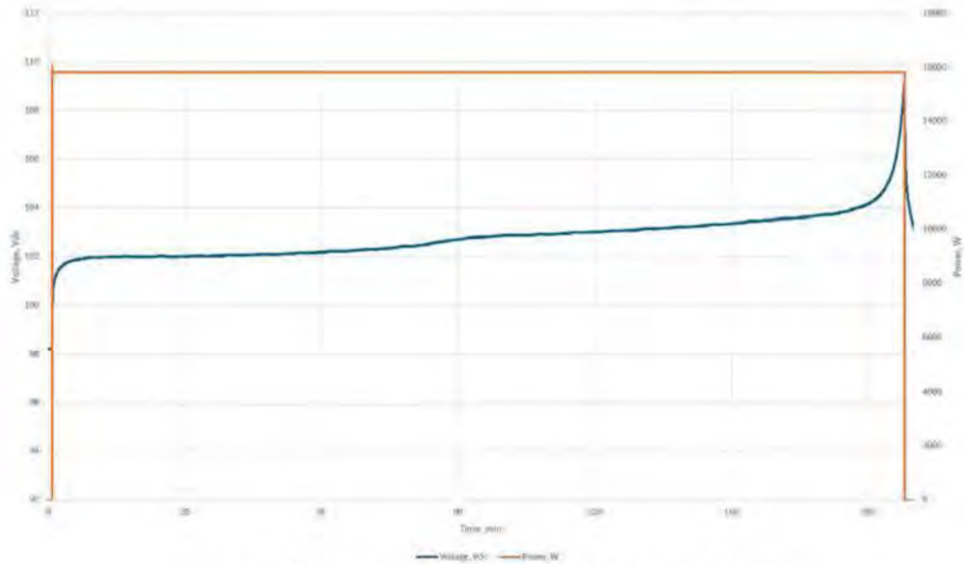


Figure A1. Initiating Module (i.e., Mod 12) Charge

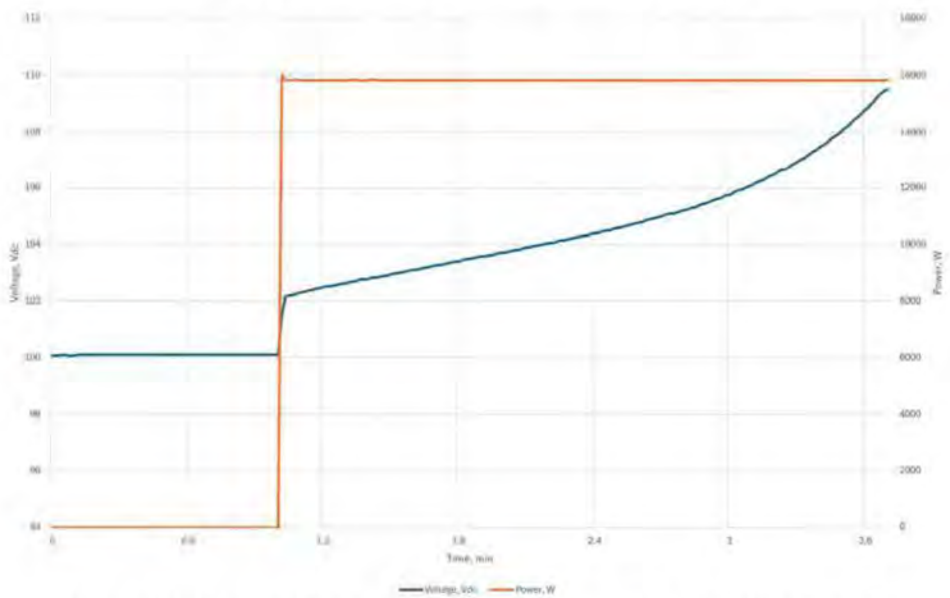


Figure A2. Initiating Module (i.e., Mod 12) Charge Top-off on the test date

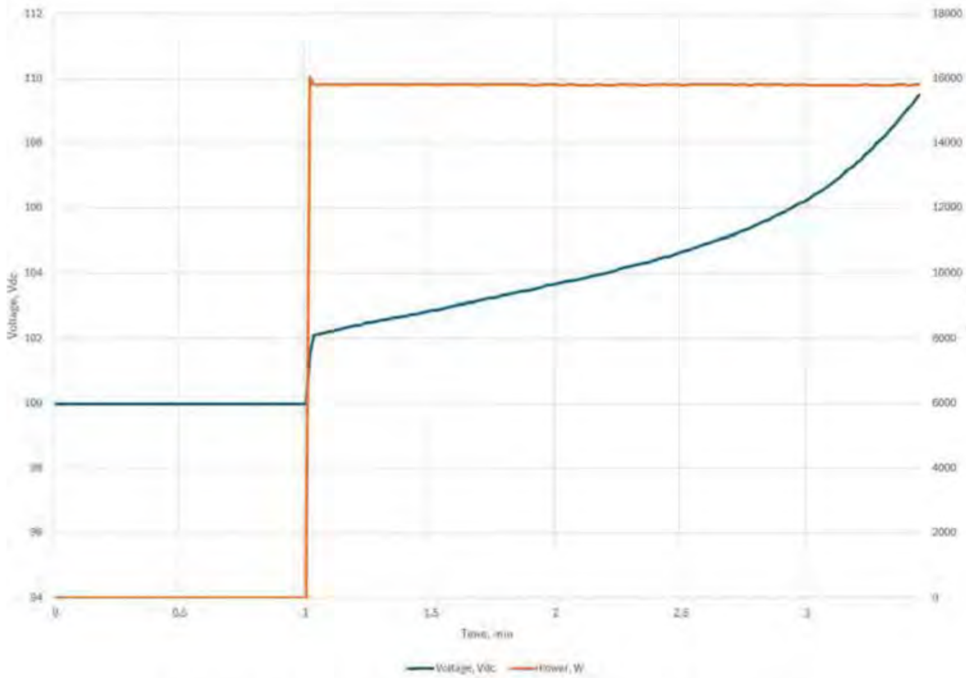


Figure A3. [2]Module 1 (i.e., Mod 1) Charge on the test date

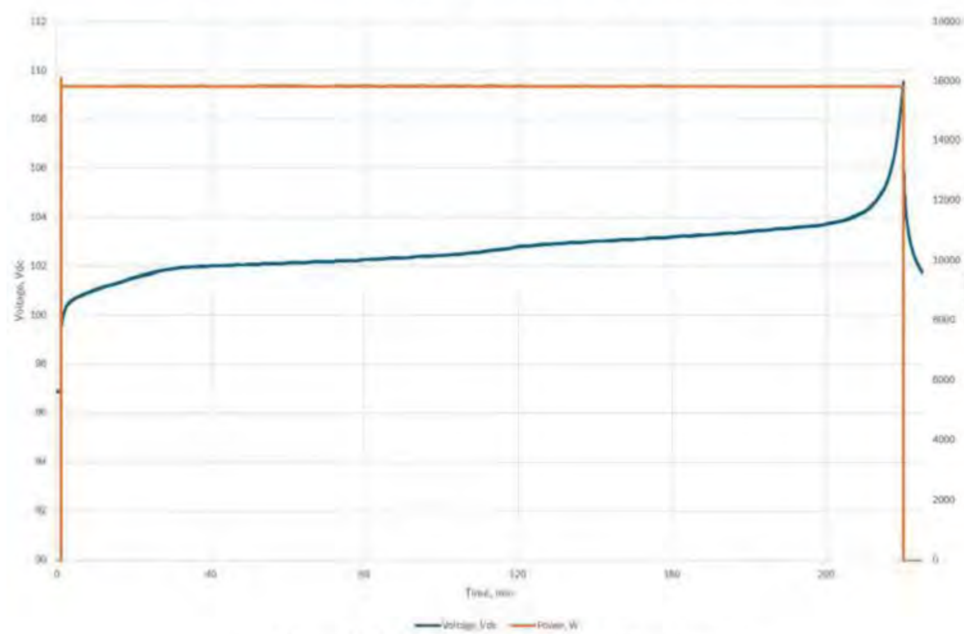


Figure A4. Module 2 (i.e., Mod 2) Charge

[2] This module was delivered in SOC 100 %. That's why the module's charging takes a little and the top-off was not required.

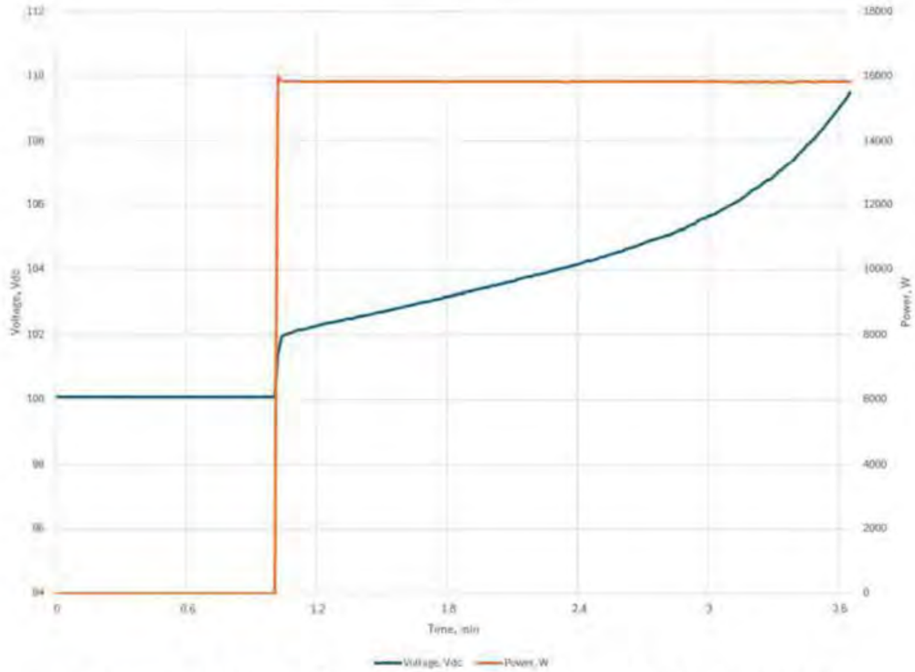


Figure A5. Module 2 (i.e., Mod 2) Charge Top-off on the test date

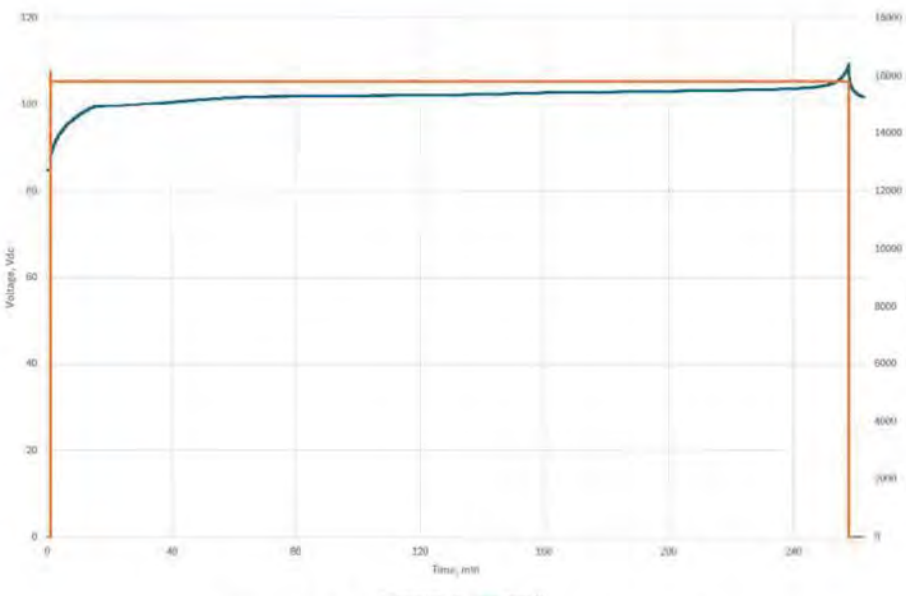


Figure A6. Module 3 (i.e., Mod 3) Charge

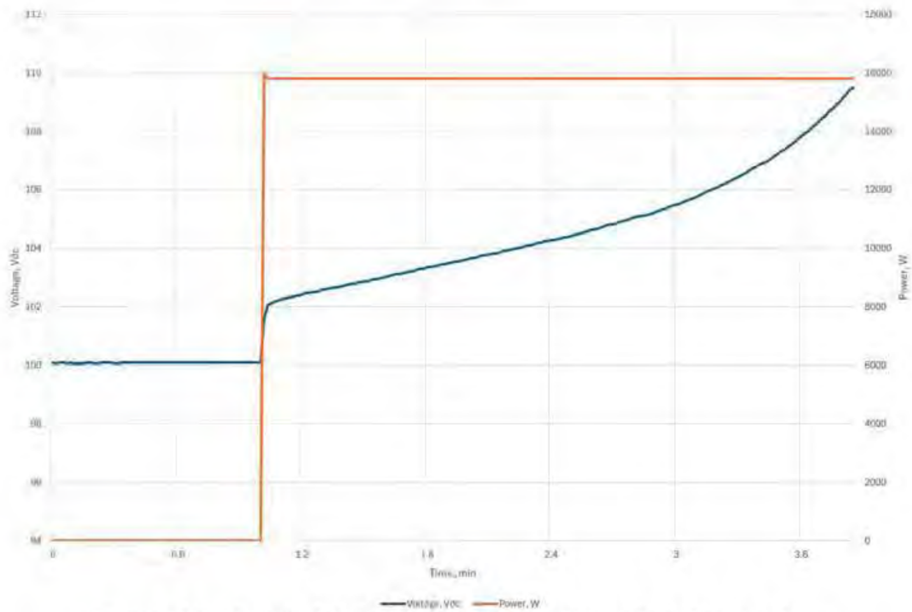


Figure A7. Module 3 (i.e., Mod 3) Charge Top-off on the test date

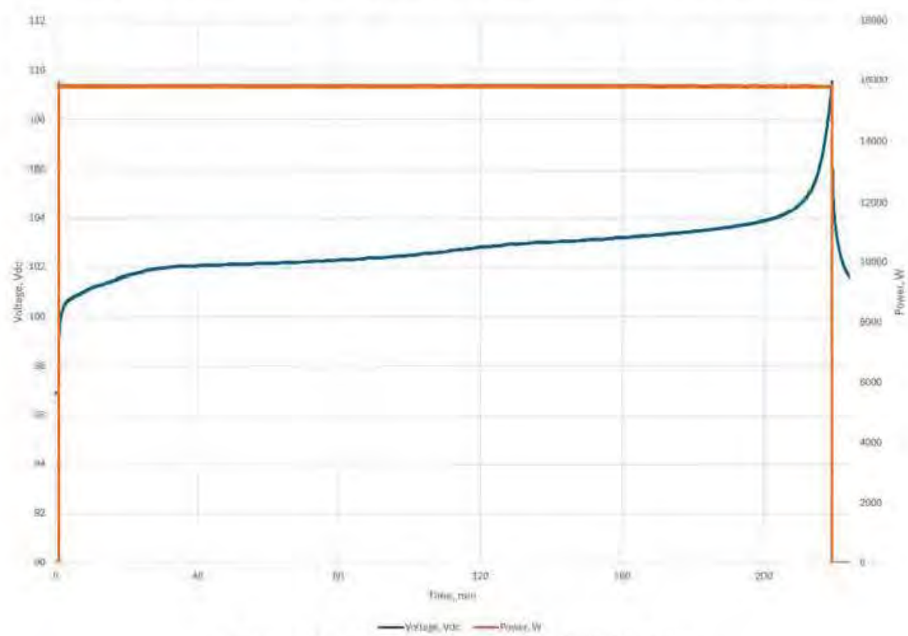


Figure A8. Module 4 (i.e., Mod 4) Charge

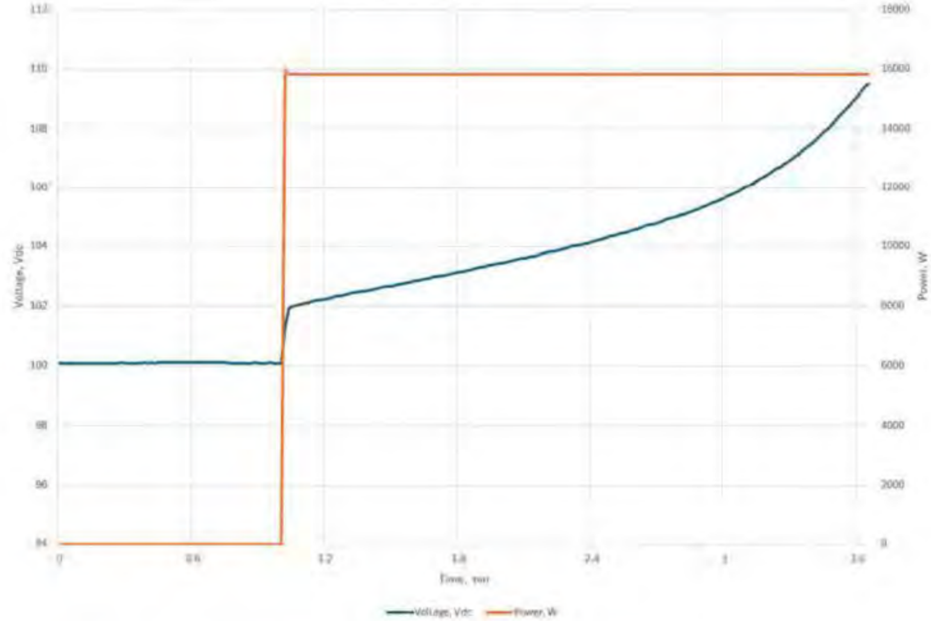


Figure A9. Module 4 (i.e., Mod 4) Charge Top-off on the test date

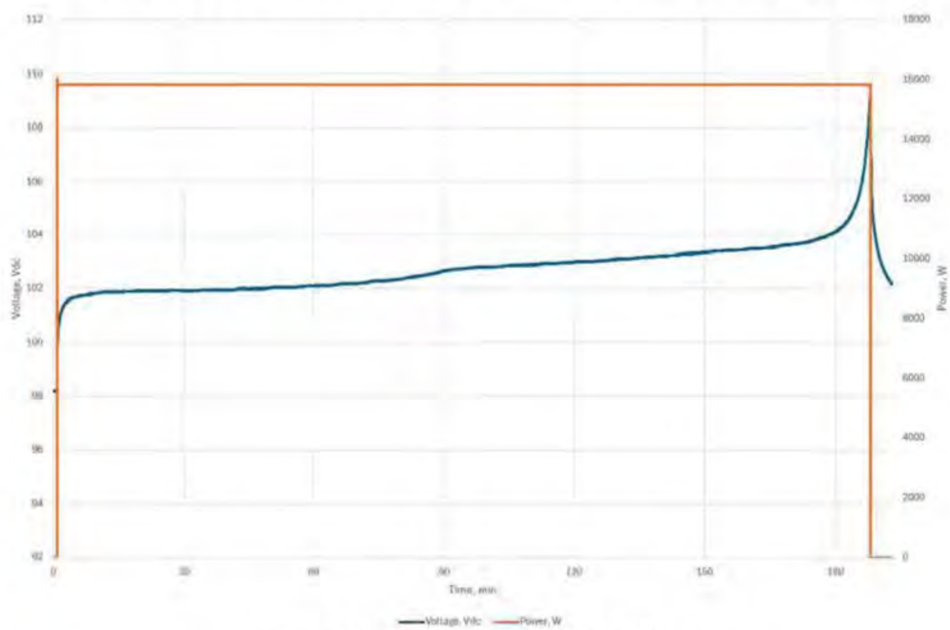


Figure A10. Module 5 (i.e., Mod 5) Charge

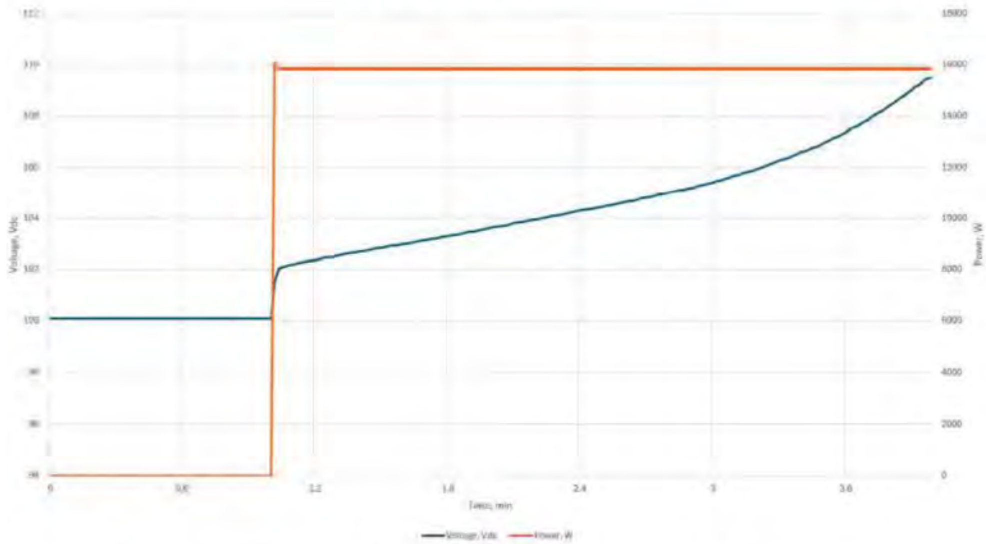


Figure A11. Module 5 (i.e., Mod 5) Charge Top-off on the test date

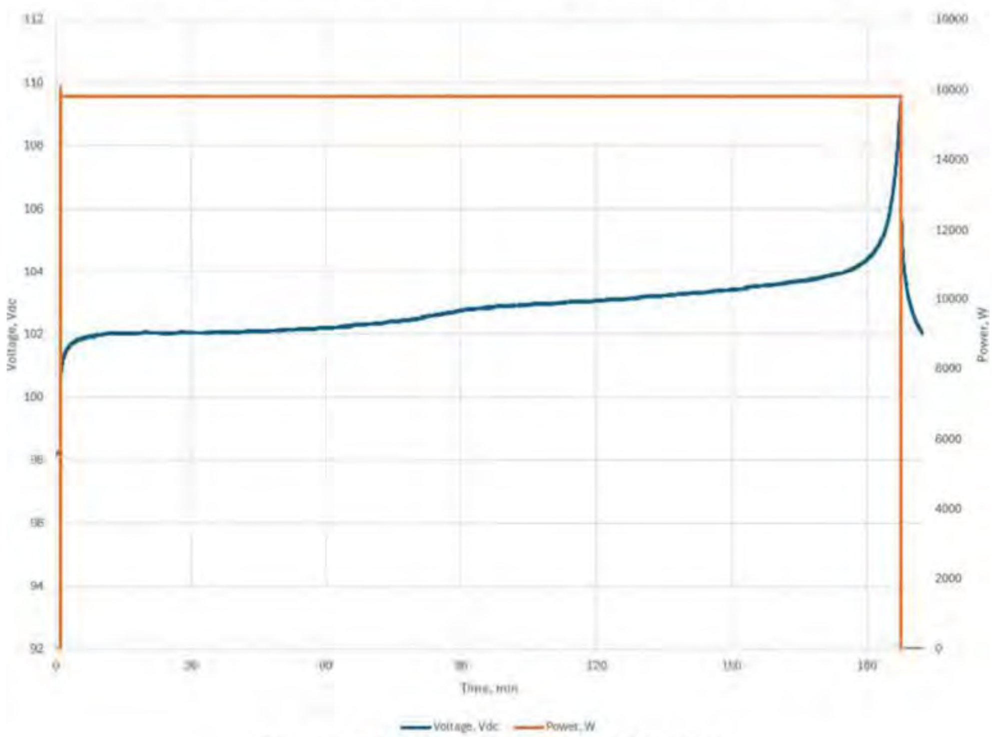


Figure A12. Module 6 (i.e., Mod 6) Charge

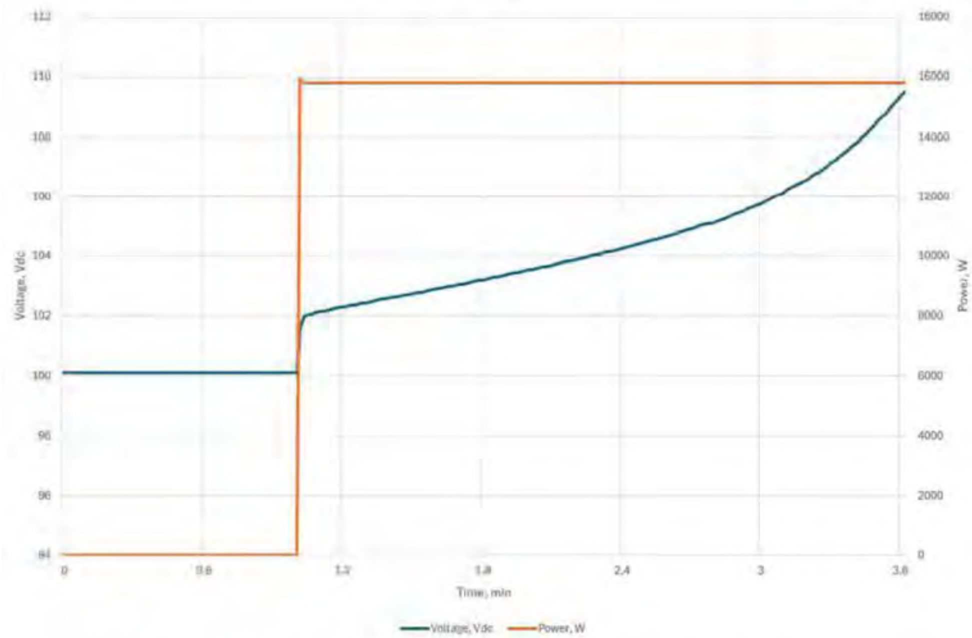


Figure A13. Module 6 (i.e., Mod 6) Charge Top-off on the test date

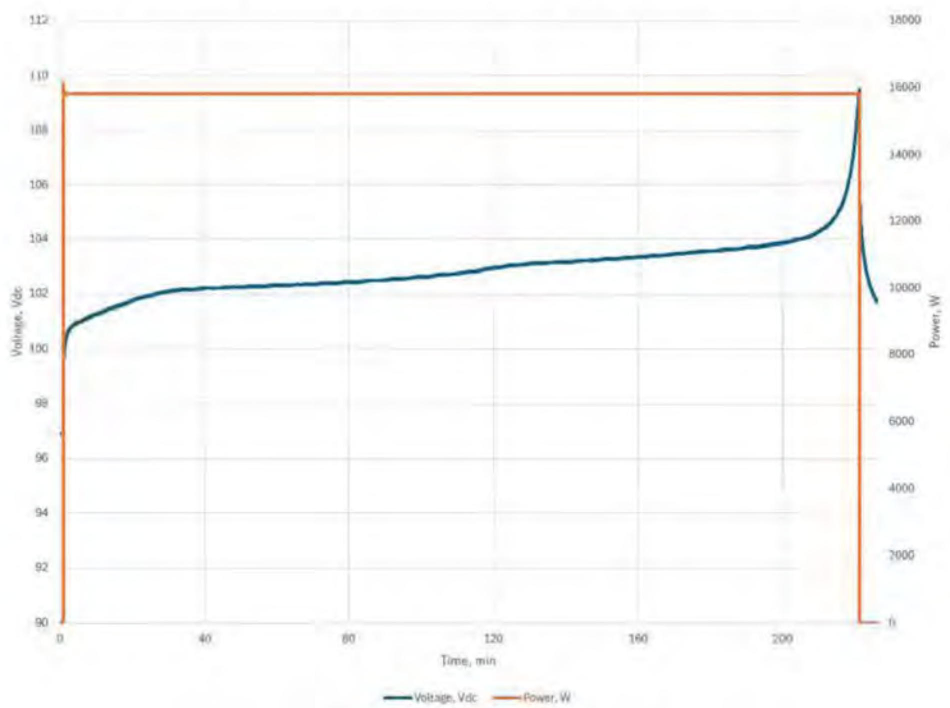


Figure A14. Module 7 (i.e., Mod 7) Charge

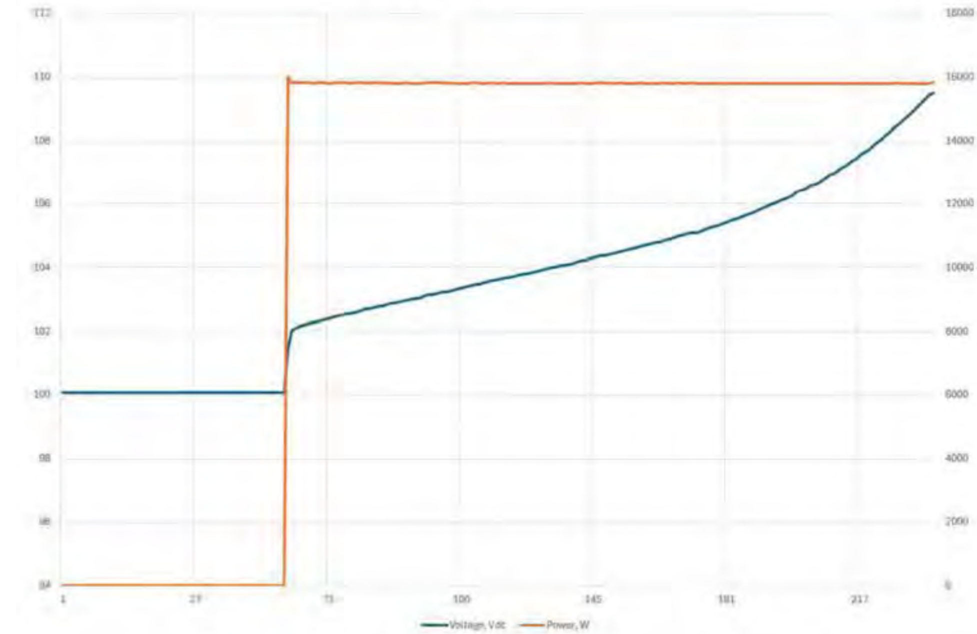


Figure A15. Module 7 (i.e., Mod 7) Charge Top-off on the test date

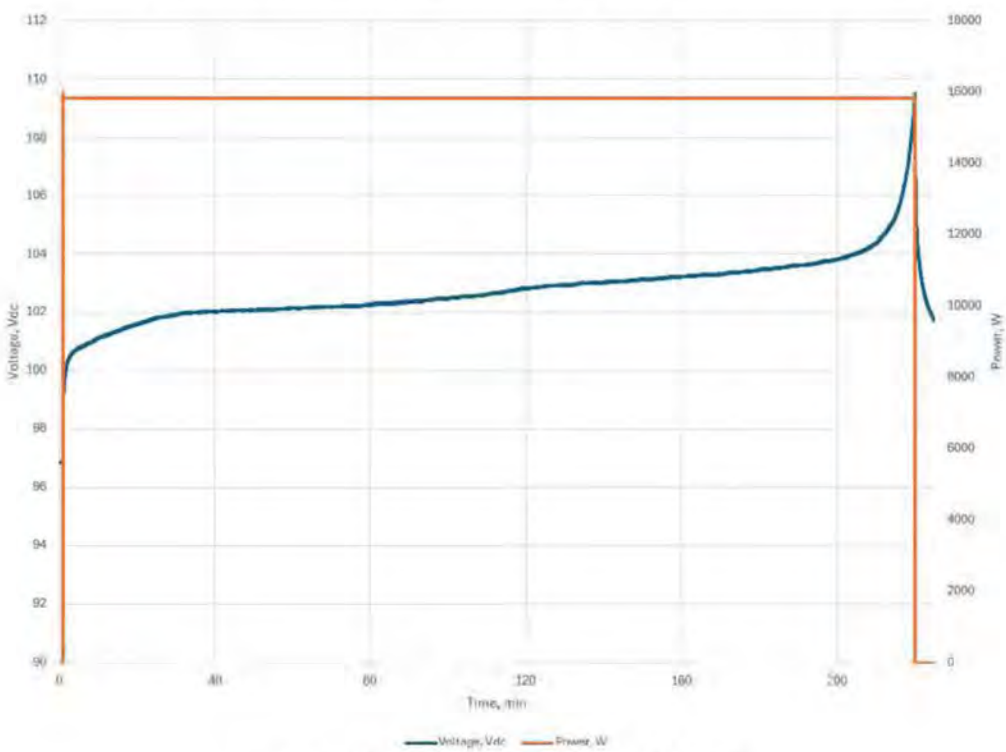


Figure A16. Module 8 (i.e., Mod 8) Charge

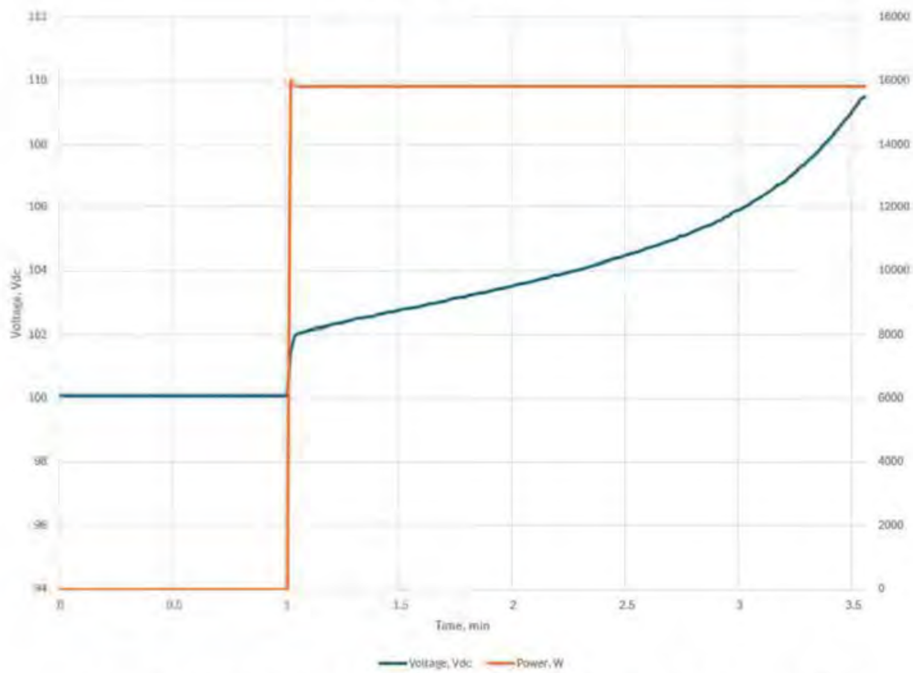


Figure A17. Module 8 (i.e., Mod 8) Charge Top-off on the test date

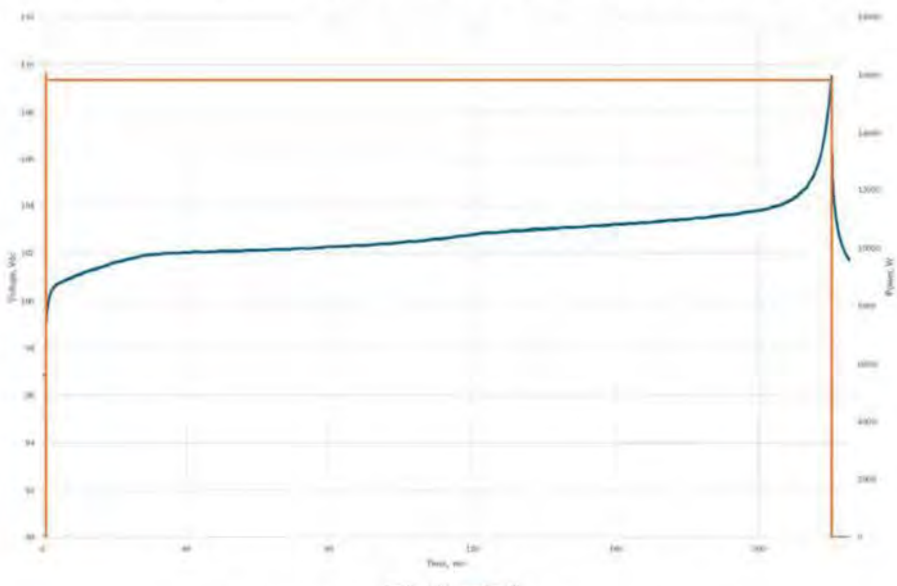


Figure A18. Module 9 (i.e., Mod 9) Charge

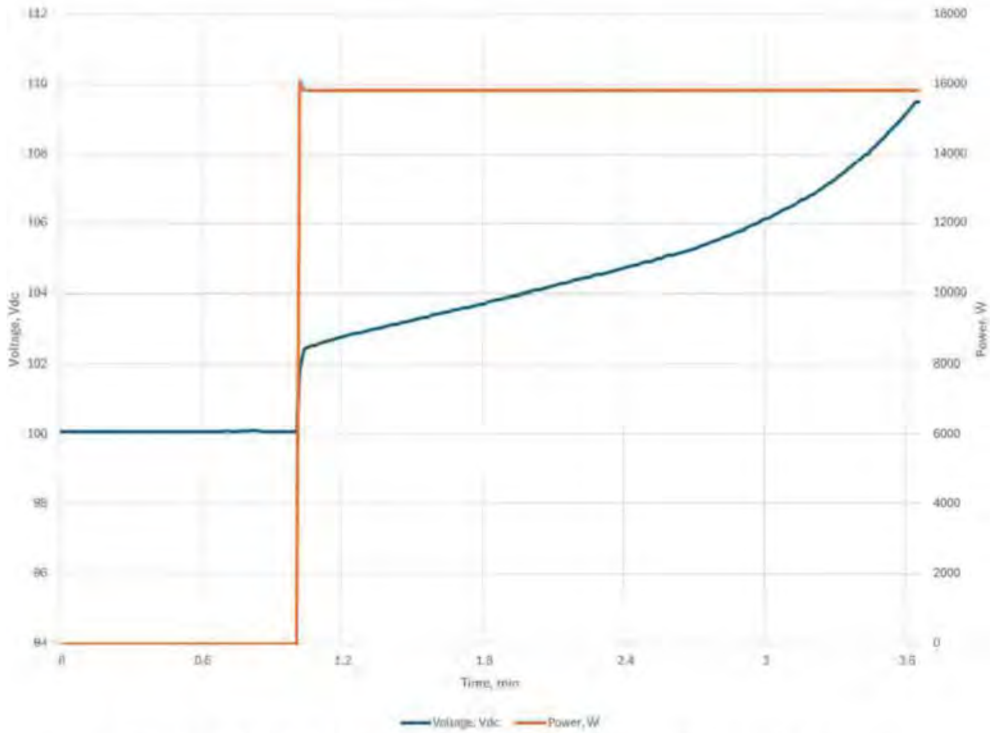


Figure A19. Module 9 (i.e., Mod 9) Charge Top-off on the test date

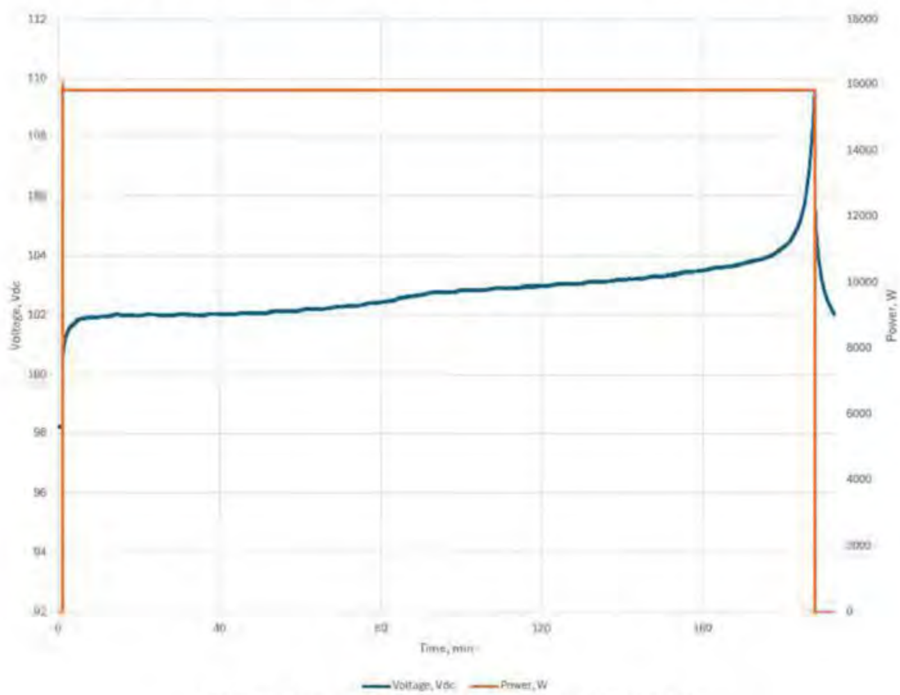


Figure A20. Module 10 (i.e., Mod 10) Charge

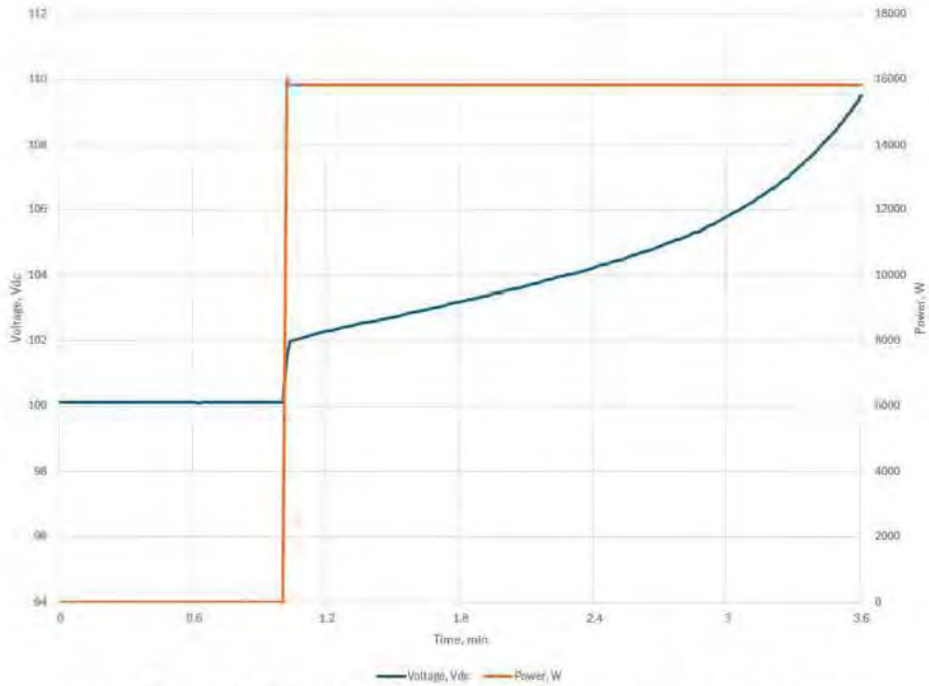


Figure A21. Module 10 (i.e., Mod 10) Charge Top-off on the test date

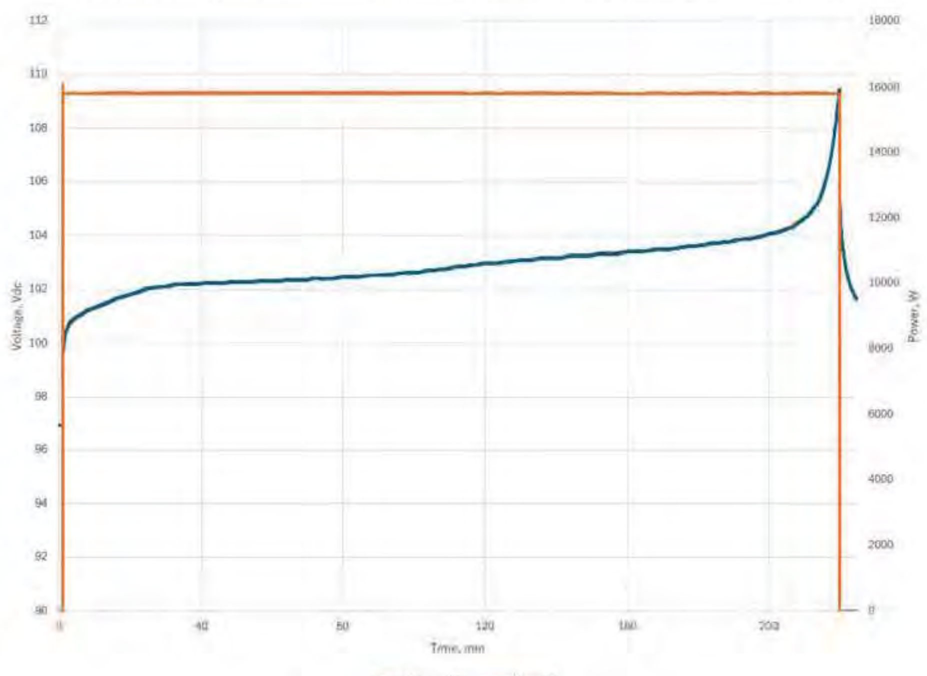


Figure A22. Module 11 (i.e., Mod 11) Charge

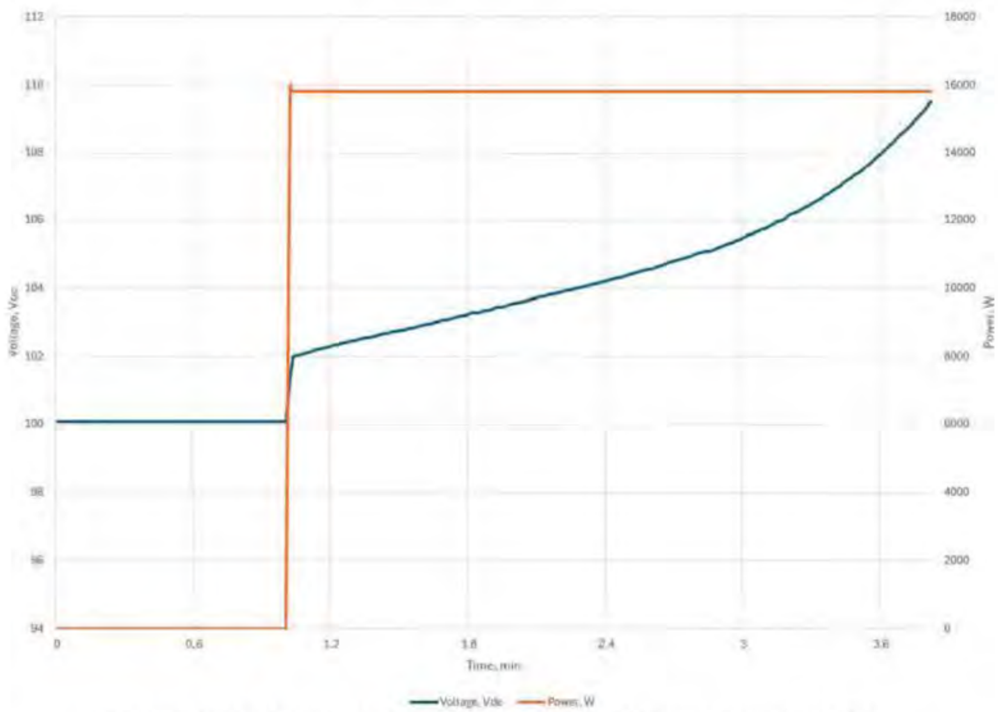


Figure A23. Module 11 (i.e., Mod 11) Charge Top-off on the test date

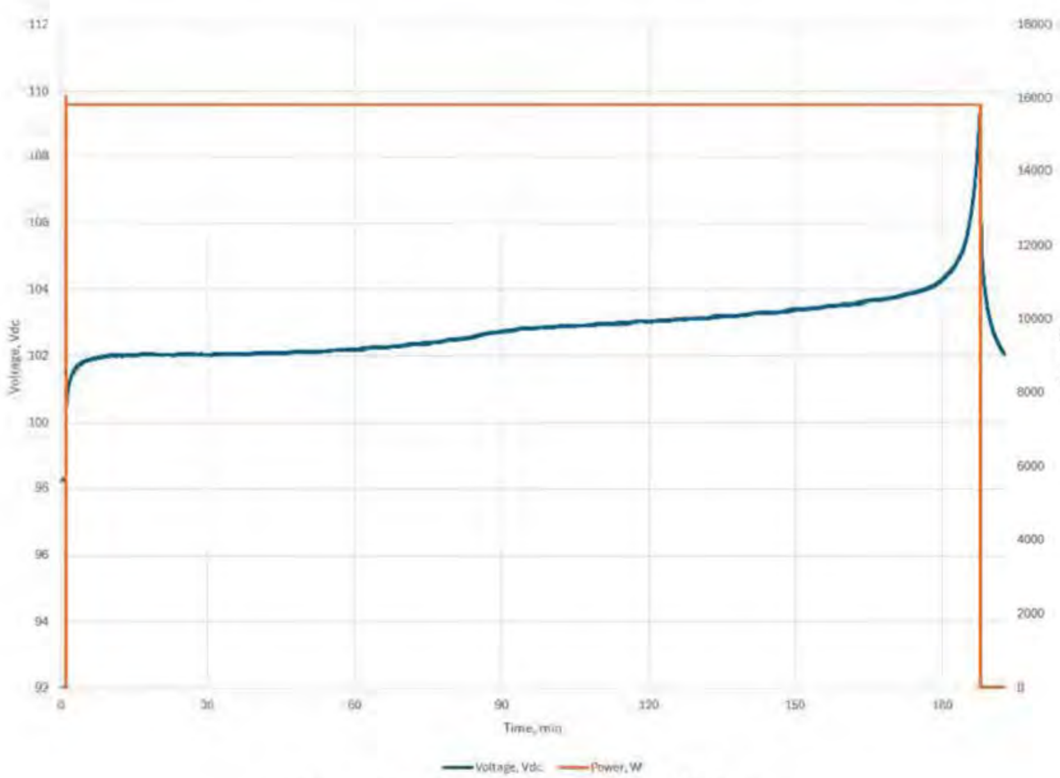


Figure A24. Module 13 (i.e., Mod 13) Charge

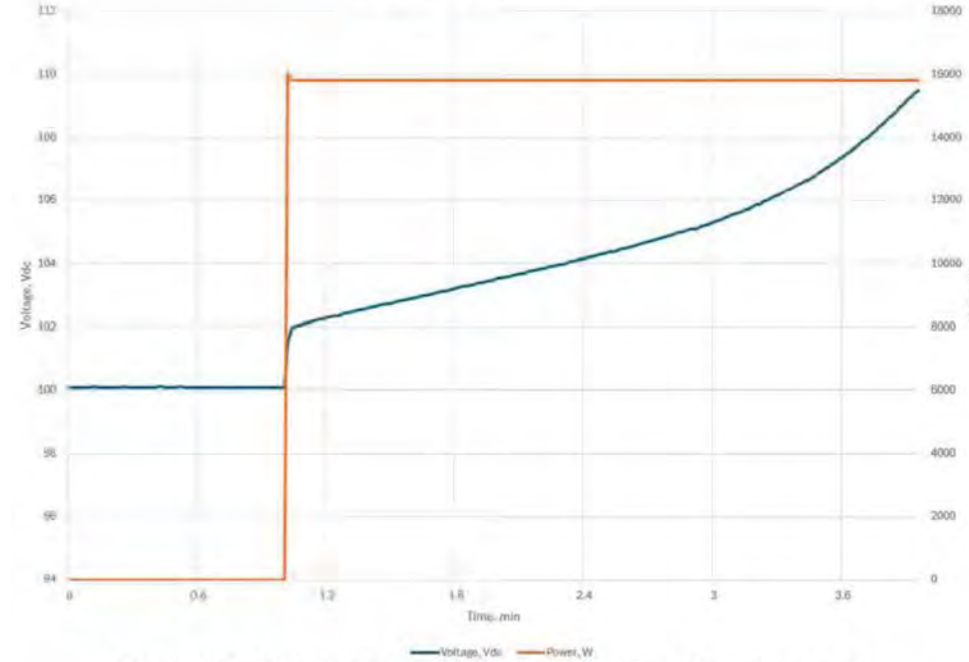


Figure A25. Module 13 (i.e., Mod 13) Charge Top-off on the test date

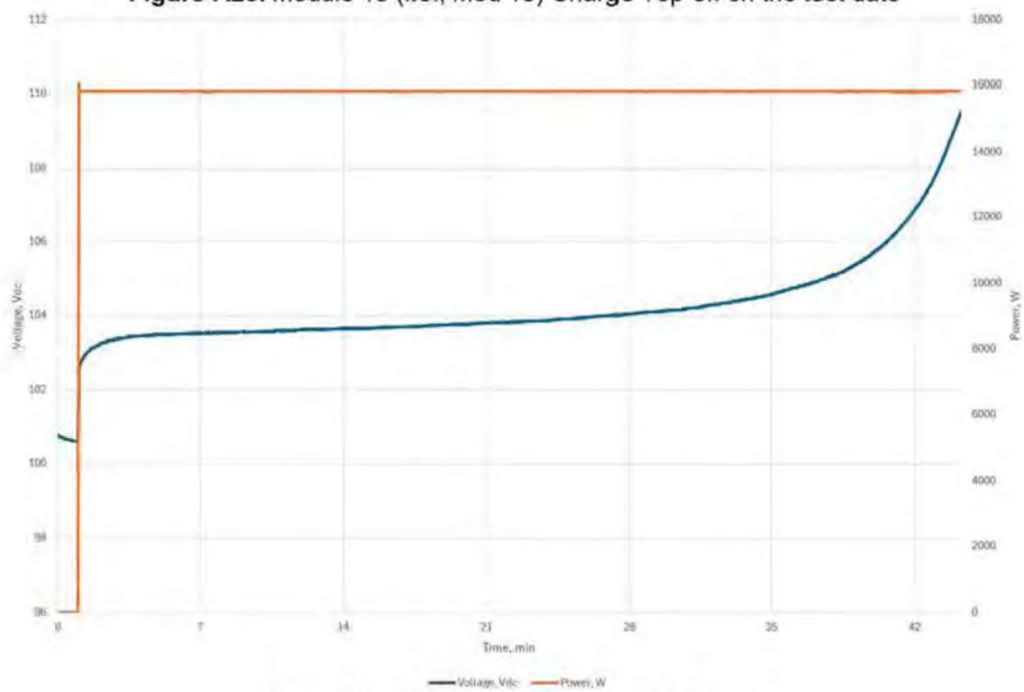


Figure A26. Module 14 (i.e., Mod 14) Charge

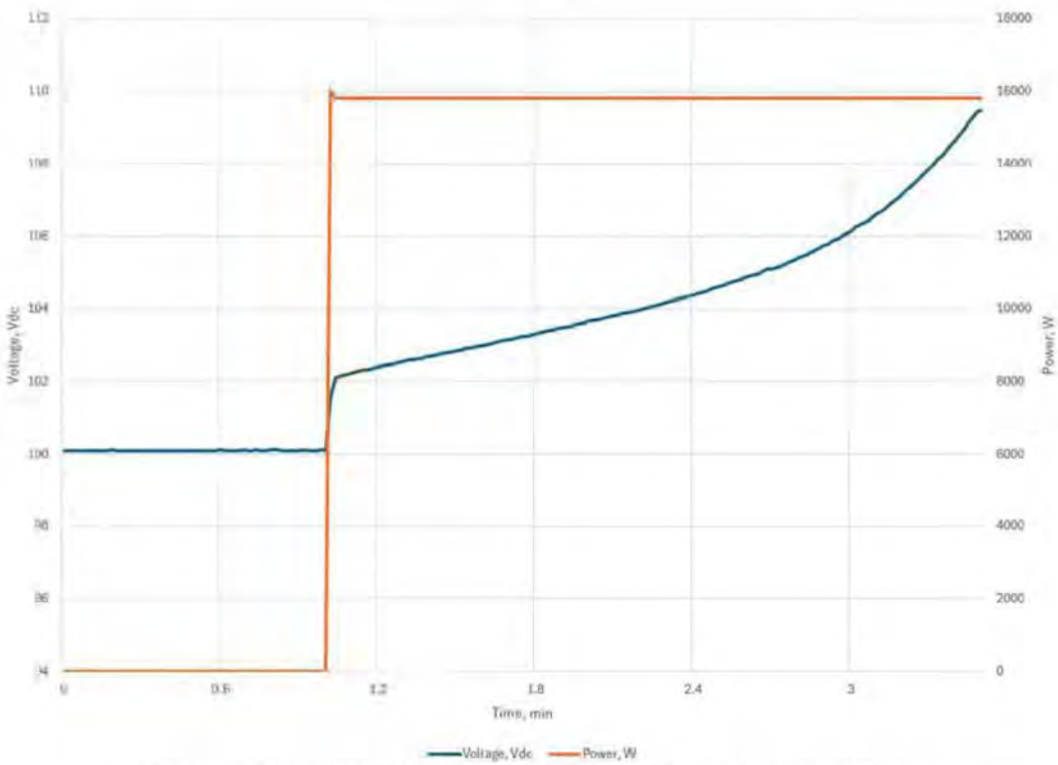
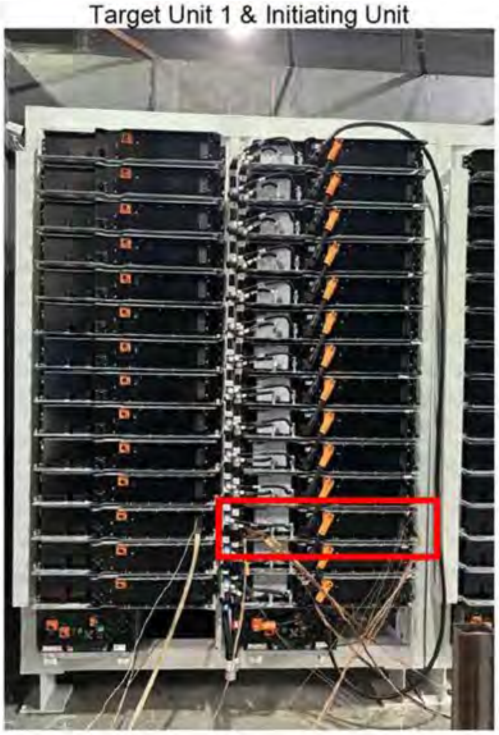


Figure A27. Module 14 (i.e., Mod 14) Charge Top-off on the test date

Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams - (*Pages **41** through **41***)

Target Unit 1 & Initiating Unit



Target 2

Figure B1. Photos of the Initiating and Target Units[3] / Initiating module (Third module from the bottom)

Figure B2. Overall view of test configuration

[3] Target units were composed of dummy modules excluding live cells, coolant, and wires for connection.

Attachment C: : BESS and Equipment Instrumentation and Test Installation Layout Photos/Diagrams - (*Pages **42** through **51***)

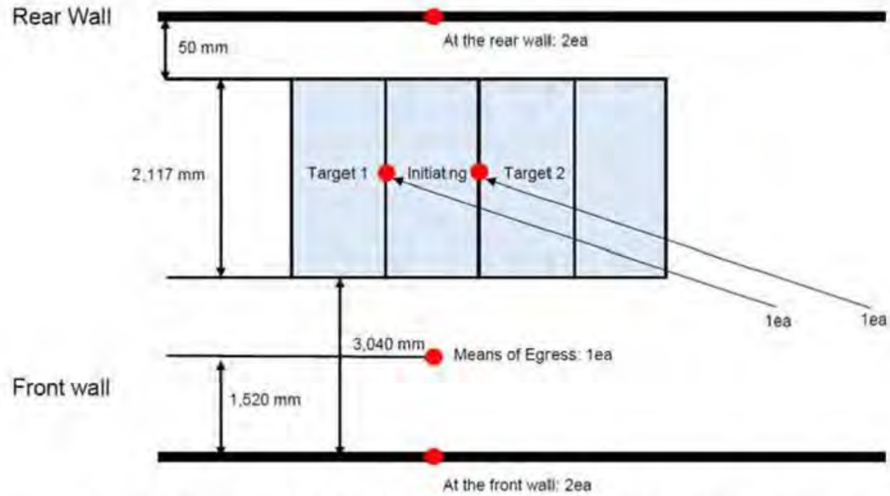
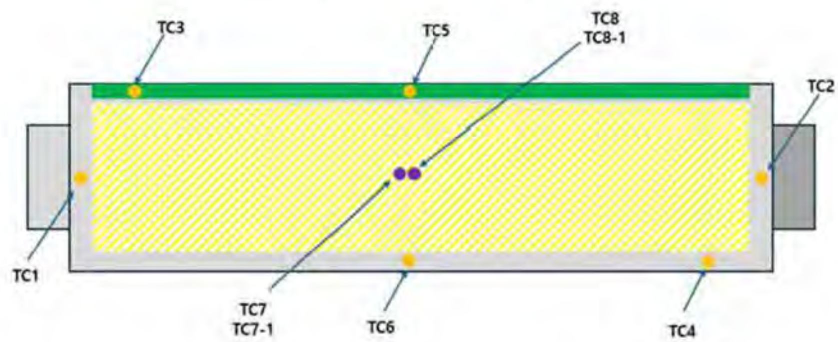
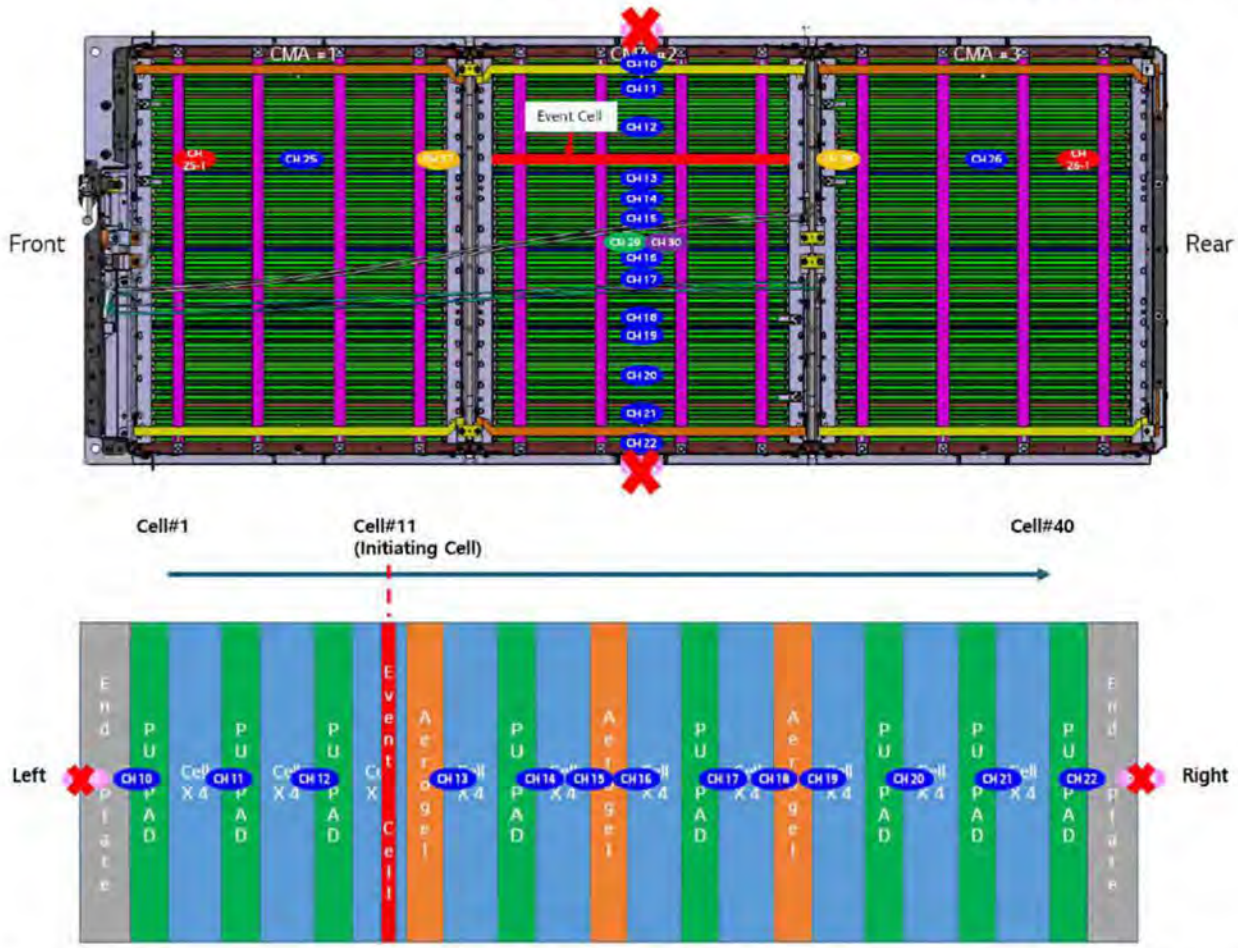


Figure C1. Overall test installation layout & Heat Flux Gauge Plan



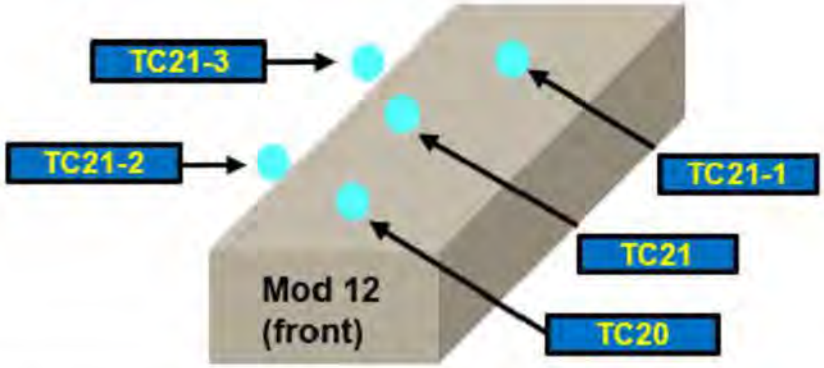
TC #	TC Location
TC1	Positive (+) Terrace
TC2	Negative (-) Terrace
TC3	Positive (+) Cell Body, serves to report venting and thermal runaway temperature
TC4	Negative (-) Cell Body, serves to report venting and thermal runaway temperature
TC5	Cell Side
TC6	Cell Side
TC7	Center 1, Under heater, Heater Control
TC7-1	Opposite cell surface, Center 1, under heater, heater control
TC8	Center 2, Under heater, Heater Control Back up
TC8-1	Opposite cell surface, Center 2, under heater, heater control

Figure C2. Thermocouple Locations for the Initiating Cell



CH#	Description of Thermocouple Location	CH#	Description of Thermocouple Location
CH10	Pad right next to Cell#1	CH21	Cell#37
CH11	Cell#4	CH22	Pad right next to Cell#40
CH12	Cell#8	CH25	Center of Cell#11 in CMA#1
CH13	Cell#13	CH25-1	Body of Cell#11 in CMA#1
CH14	Cell#17	CH26	Center of Cell#11 in CMA#3
CH15	Cell#20	CH26-1	Body of Cell#11 in CMA#3
CH16	Cell#21	CH27	Mica sheet between CMA#1 and CMA#2
CH17	Cell#25	CH28	Mica sheet between CMA#2 and CMA#3
CH18	Cell#28	CH29	Upper side of Heat sink at bottom
CH19	Cell#29	CH30	Lower side of Top cover
CH20	Cell#33		

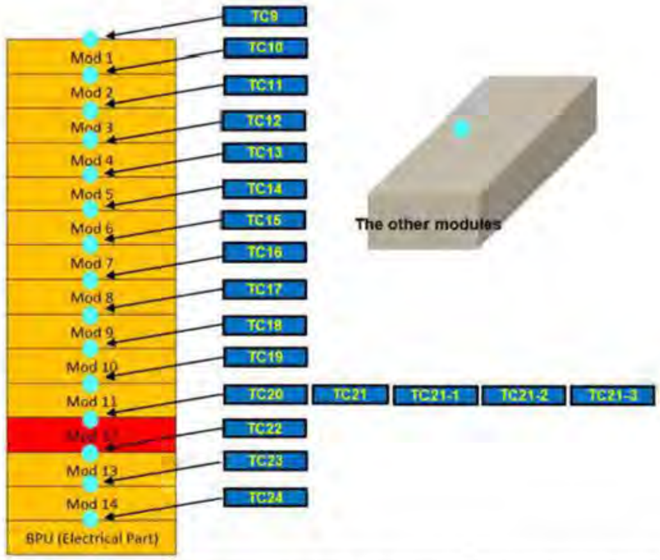
Figure C3. Thermocouple Locations for the Initiating Module (Internal)



Thermocouple #	Description of Thermocouple Location
TC20	Front of Top Cover
TC21	Point right above the initiating Cell on Top Cover
TC21-1	Rear of Top Cover
TC21-2	Front Vent hole on left side
TC21-3	Rear Vent hole on left side

Figure C4. [4]Thermocouple Locations for the Initiating Module (External)

[4] The TC21-2 and TC21-3 were not depressed into the vent hole to be flush with the vent hole surface. Because it's for measurement of gas.



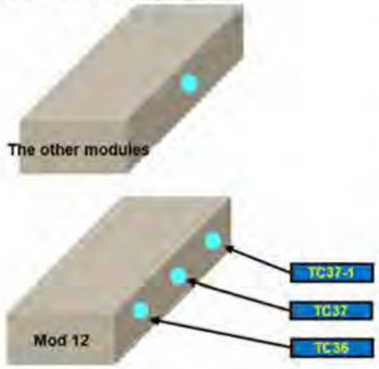
Thermocouple #	Description of Thermocouple Location
TC9	Initiating Unit, Module 1 (i.e., IniMod1)
TC10	Initiating Unit, Module 2 (i.e., IniMod2)
TC11	Initiating Unit, Module 3 (i.e., IniMod3)
TC12	Initiating Unit, Module 4 (i.e., IniMod4)
TC13	Initiating Unit, Module 5 (i.e., IniMod5)
TC14	Initiating Unit, Module 6 (i.e., IniMod6)
TC15	Initiating Unit, Module 7 (i.e., IniMod7)
TC16	Initiating Unit, Module 8 (i.e., IniMod8)
TC17	Initiating Unit, Module 9 (i.e., IniMod9)
TC18	Initiating Unit, Module 10 (i.e., IniMod10)
TC19	Initiating Unit, Module 11 (i.e., IniMod11)
TC20	Please refer to Figure C4.
TC21	Please refer to Figure C4.
TC21-1	Please refer to Figure C4.
TC21-2	Please refer to Figure C4.
TC21-3	Please refer to Figure C4.
TC22	Initiating Unit, Module 13 (i.e., IniMod13)
TC23	Initiating Unit, Module 14 (i.e., IniMod14)
TC24	Initiating Unit, BPU (Electrical Part) (i.e., IniBPU)

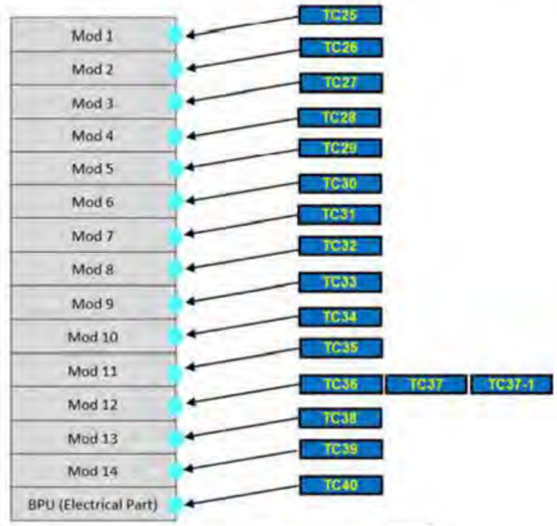
Figure C5. [5]Thermocouple Locations for the Initiating Unit

[5] For TC20 to TC21-3, please refer to Figure C4 for further details.

Target 1 Unit TC's

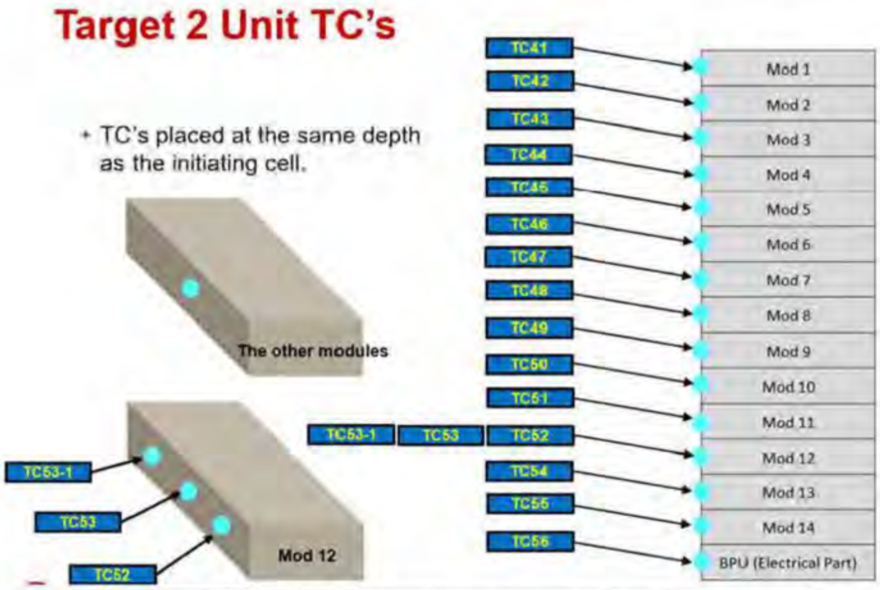
- TC's placed at the same depth as the initiating cell.





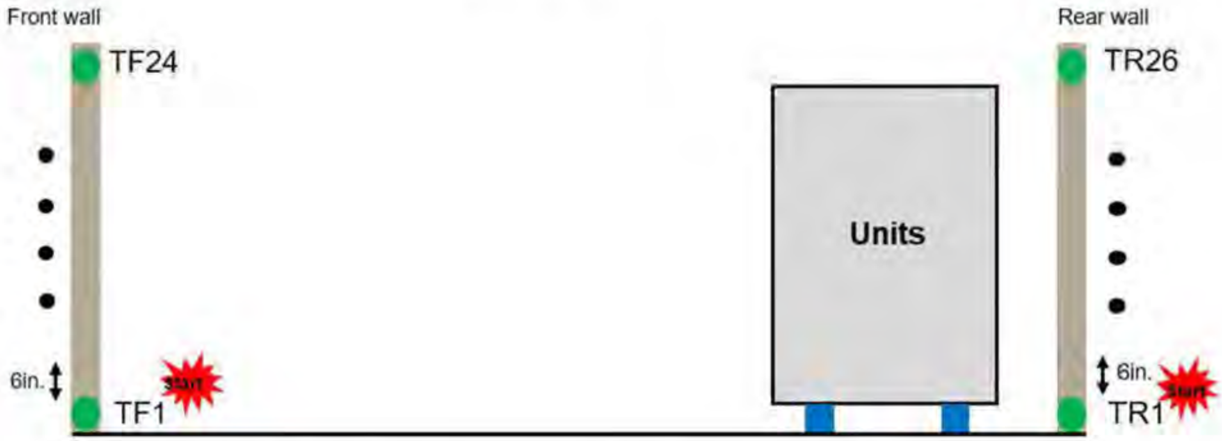
Thermocouple #	Description of Thermocouple Location
TC25	Target 1, Module 1 (i.e., T1Mod1)
TC26	Target 1, Module 2 (i.e., T1Mod2)
TC27	Target 1, Module 3 (i.e., T1Mod3)
TC28	Target 1, Module 4 (i.e., T1Mod4)
TC29	Target 1, Module 5 (i.e., T1Mod5)
TC30	Target 1, Module 6 (i.e., T1Mod6)
TC31	Target 1, Module 7 (i.e., T1Mod7)
TC32	Target 1, Module 8 (i.e., T1Mod8)
TC33	Target 1, Module 9 (i.e., T1Mod9)
TC34	Target 1, Module 10 (i.e., T1Mod10)
TC35	Target 1, Module 11 (i.e., T1Mod11)
TC36	Target 1, Module 12 (i.e., T1Mod12Front)
TC37	Target 1, Module 12 (i.e., T1Mod12Center)
TC37-1	Target 1, Module 12 (i.e., T1Mod12Rear)
TC38	Target 1, Module 13 (i.e., T1Mod13)
TC39	Target 1, Module 14 (i.e., T1Mod14)
TC40	Target 1, BPU (i.e., T1BPU)

Figure C6. Thermocouple Locations for the Target Unit 1



Thermocouple #	Description of Thermocouple Location
TC41	Target 2, Module 1 (i.e., T2Mod1)
TC42	Target 2, Module 2 (i.e., T2Mod2)
TC43	Target 2, Module 3 (i.e., T2Mod3)
TC44	Target 2, Module 4 (i.e., T2Mod4)
TC45	Target 2, Module 5 (i.e., T2Mod5)
TC46	Target 2, Module 6 (i.e., T2Mod6)
TC47	Target 2, Module 7 (i.e., T2Mod7)
TC48	Target 2, Module 8 (i.e., T2Mod8)
TC49	Target 2, Module 9 (i.e., T2Mod9)
TC50	Target 2, Module 10 (i.e., T2Mod10)
TC51	Target 2, Module 11 (i.e., T2Mod11)
TC52	Target 2, Module 12 (i.e., T2Mod12Front)
TC53	Target 2, Module 12 (i.e., T2Mod12Center)
TC53-1	Target 2, Module 12 (i.e., T2Mod12Rear)
TC54	Target 2, Module 13 (i.e., T2Mod13)
TC55	Target 2, Module 14 (i.e., T2Mod14)
TC56	Target 2, BPU (i.e., T2BPU)

Figure C7. Thermocouple Locations for the Target Unit 2



Thermocouple #	Description of Thermocouple Location	Thermocouple #	Description of Thermocouple Location
TF1	0 in.	TR1	0 in.
TF2	6 in.	TR2	6 in.
TF3	12 in.	TR3	12 in.
TF4	18 in.	TR4	18 in.
TF5	24 in.	TR5	24 in.
TF6	30 in.	TR6	30 in.
TF7	36 in.	TR7	36 in.
TF8	42 in.	TR8	42 in.
TF9	48 in.	TR9	48 in.
TF10	54 in.	TR10	54 in.
TF11	60 in.	TR11	60 in.
TF12	66 in.	TR12	66 in.
TF13	72 in.	TR13	72 in.
TF14	78 in.	TR14	78 in.
TF15	84 in.	TR15	84 in.
TF16	90 in.	TR16	90 in.
TF17	96 in.	TR17	96 in.
TF18	102 in.	TR18	102 in.
TF19	108 in.	TR19	108 in.
TF20	114 in.	TR20	114 in.
TF21	120 in.	TR21	120 in.
TF22	126 in.	TR22	126 in.
TF23	132 in.	TR23	132 in.
TF24	138 in.	TR24	138 in.
--	--	TR25	144 in.
--	--	TR26	150 in.

Table C8. Thermocouple Locations on Instrumented Walls

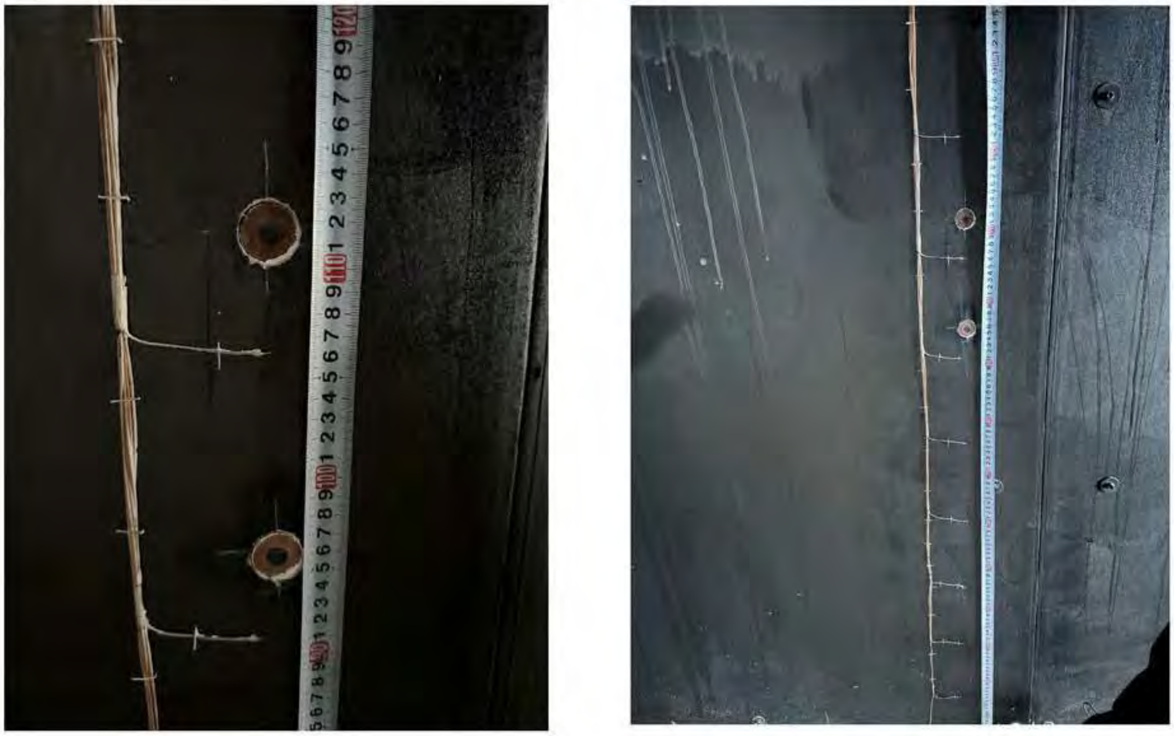


Figure C9. Heat Flux installed on the rear wall

Figure C10. Heat Flux installed on the front wall

Figure C11. Heat Flux gauges in the center of the accessible mean of egress (distance from initiating unit: 1,520 mm)

Heat flux on Target Unit 1 Heat flux on Target Unit 2

Figure C12. Heat Flux installed in Target Units

Figure C13. Distance from Rear Wall to Rear of Units. (distance from initiating unit: 500 mm)

Figure C14. Distance from Front Wall to Front of Units. (Approximately 3,040 mm from the front wall)

Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. - (*Pages **52** through **56***)

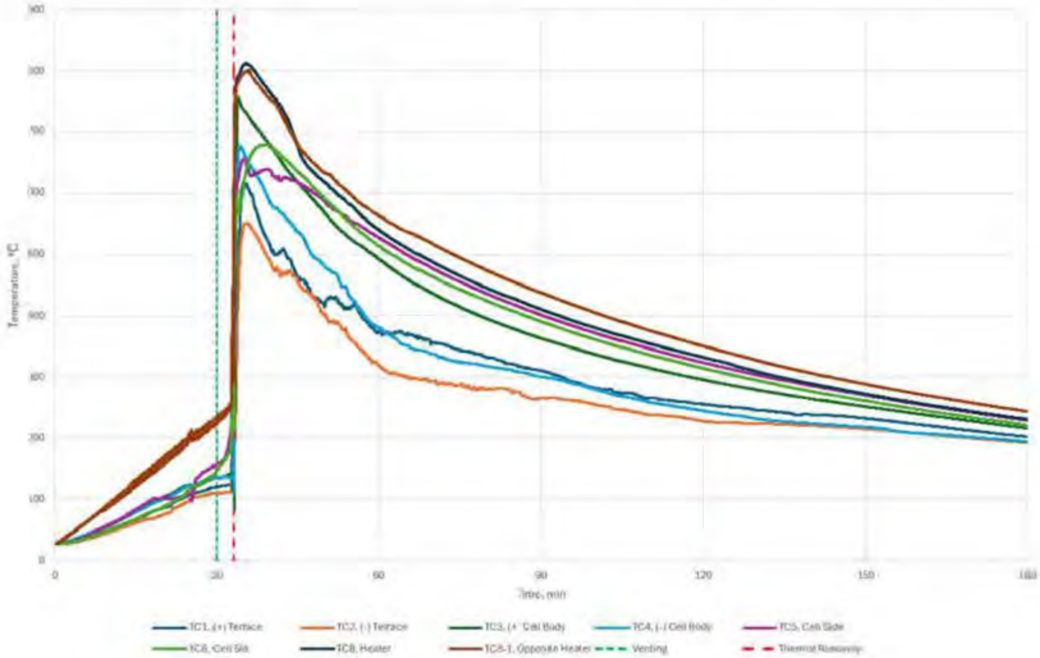


Figure D1. Initiating Cell in the initiating module

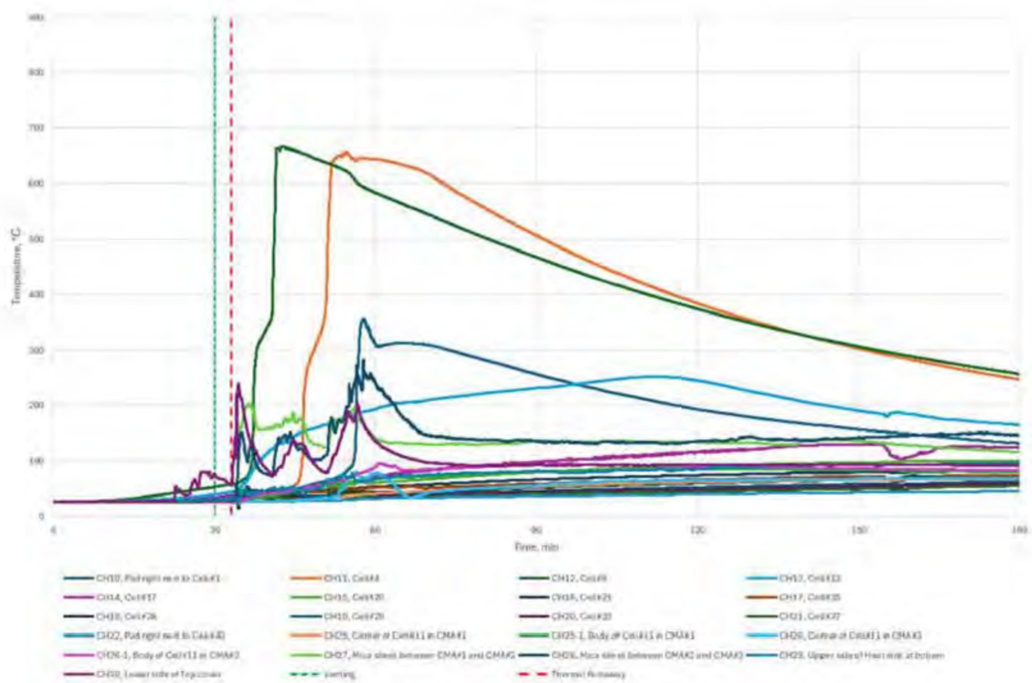


Figure D2. Thermocouples inside of the initiating module

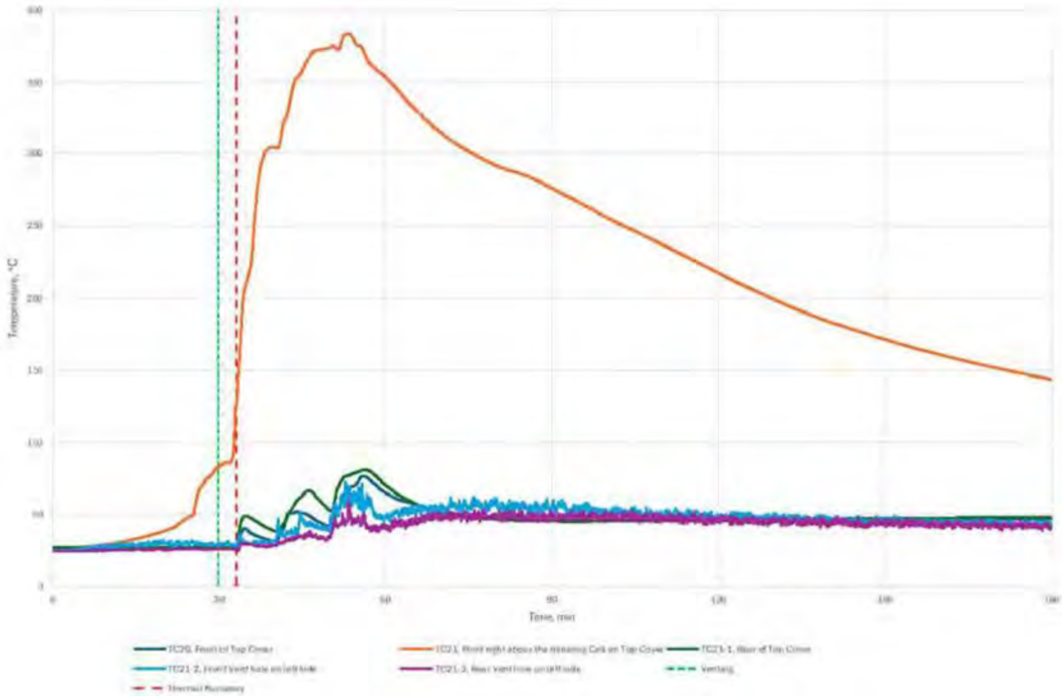


Figure D3. Thermocouples on the exterior of the initiating module

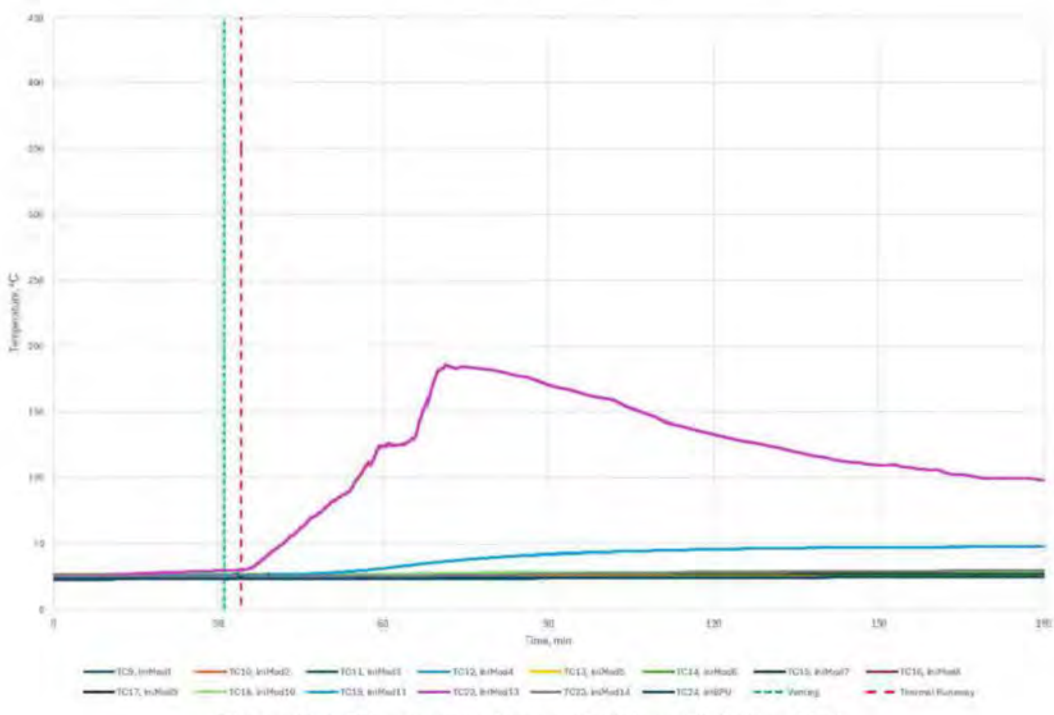


Figure D4. [6]Thermocouples on Modules in Initiating Unit

[6] For thermocouples exterior on the initiating module, please refer to Figure D3 for further details.

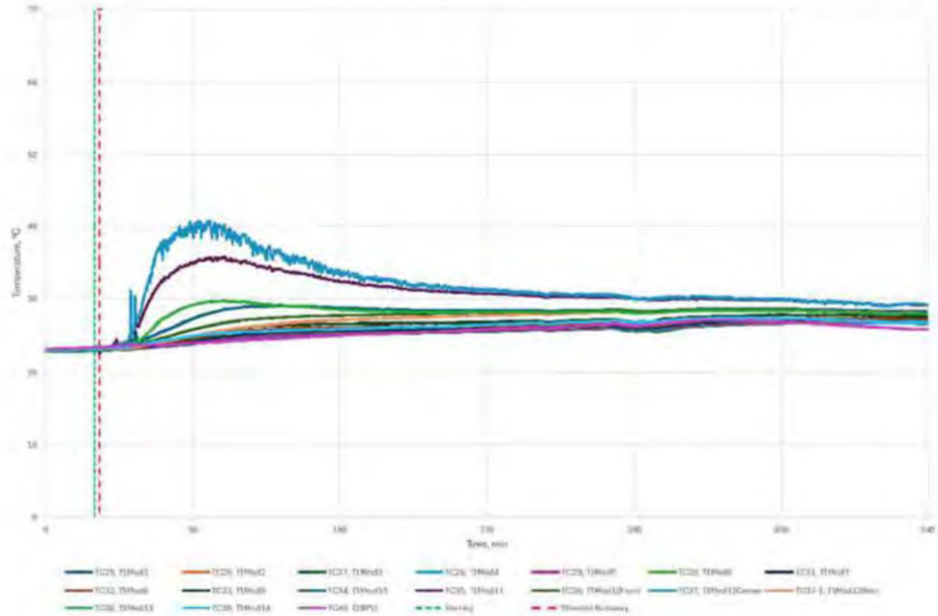


Figure D5. Thermocouples on Modules in Target Unit 1

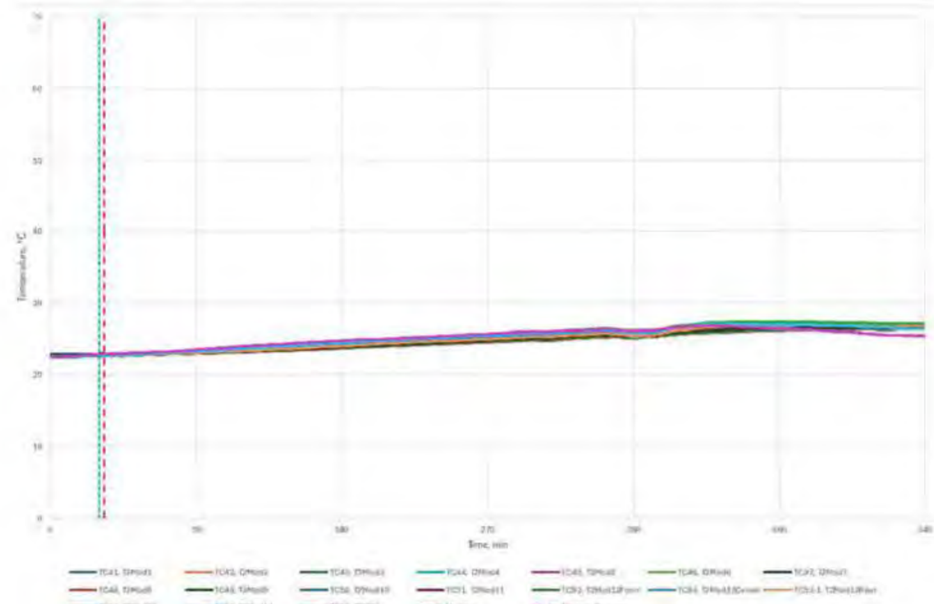


Figure D6. Thermocouples on Modules in Target Unit 2

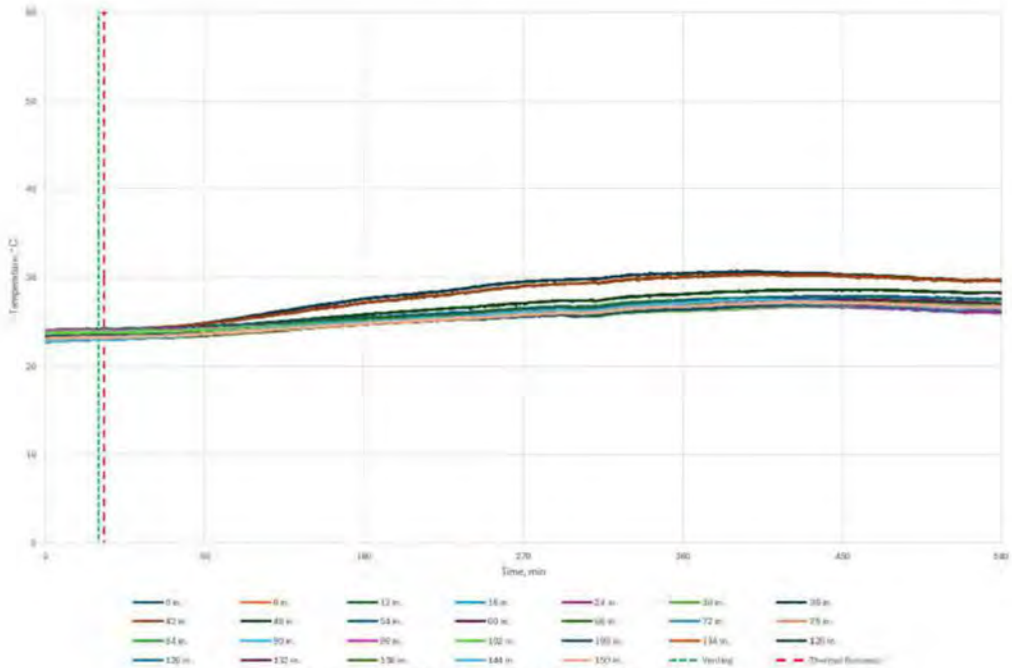


Figure D7. Thermocouples on Rear Wall

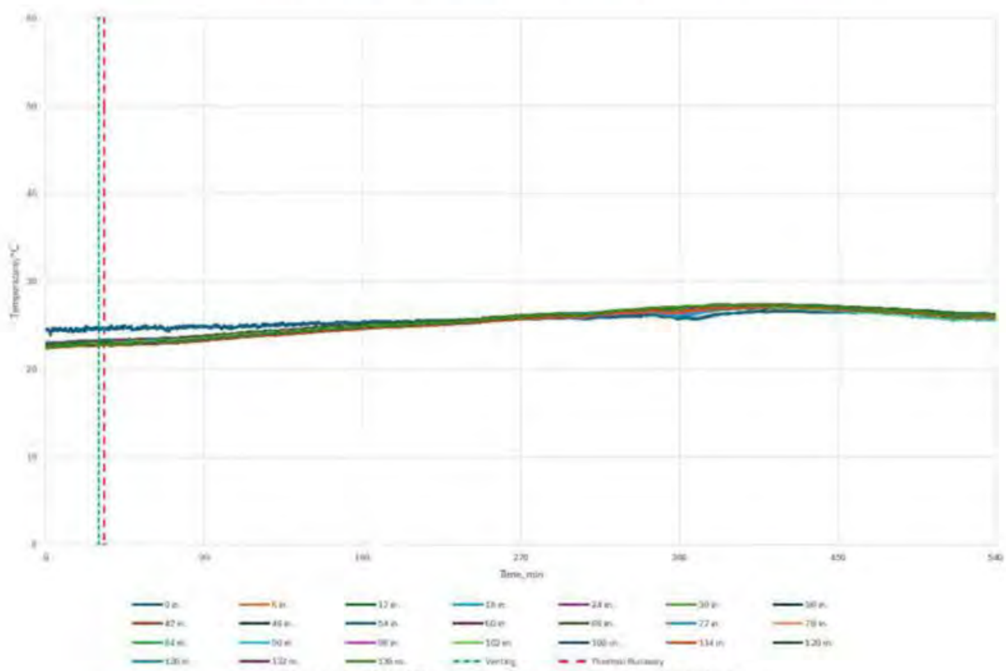


Figure D8. Thermocouples on Front Wall

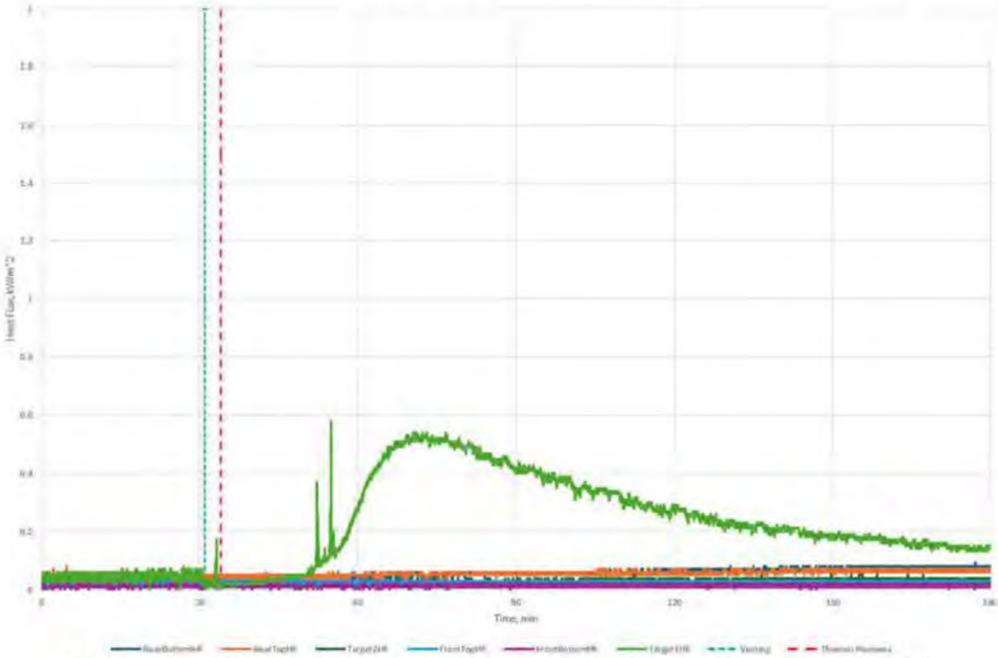


Figure D8. Heat Flux Measurements during the Unit Test (Targets and Walls)

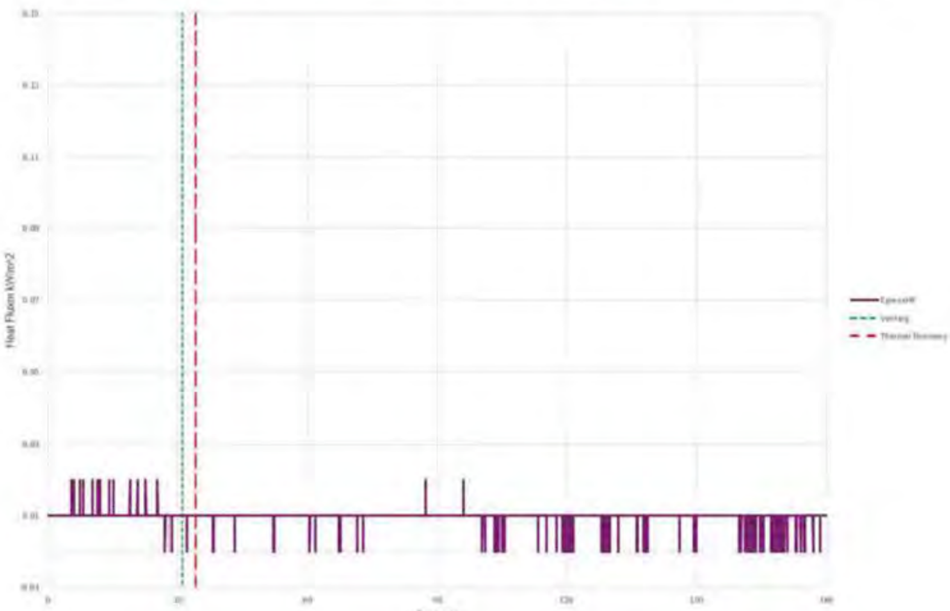


Figure D9. Heat Flux Measurements during the Unit Test (Egress)

Attachment E: BESS Unit Testing and Post Testing Photos - (*Pages **57** through **59***)

(a) Test Start
[00:00:00]

(b) [7]Initiating Cell Vent
[00:29:53]

(c) Initiating Unit Thermal Runaway
[00:32:59]

(d) Maximum Smoke Release Rate (1.84 m^2/s)
[00:34:09]

(e) Coolant spilled out
[00:35:47]

(f) Thermal Runaway Propagation (Cell #8)
[00:35:59]

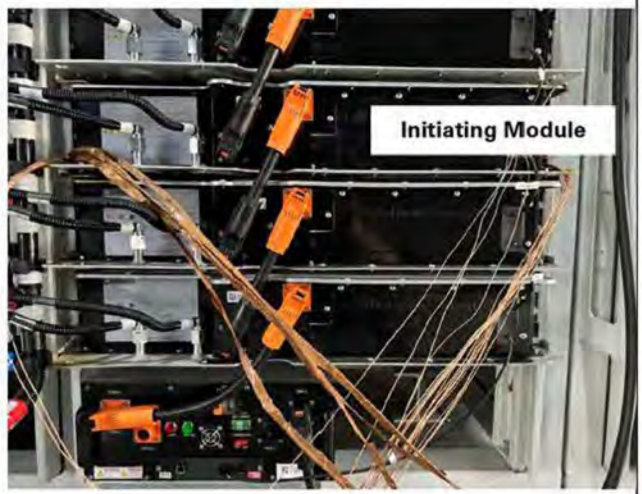
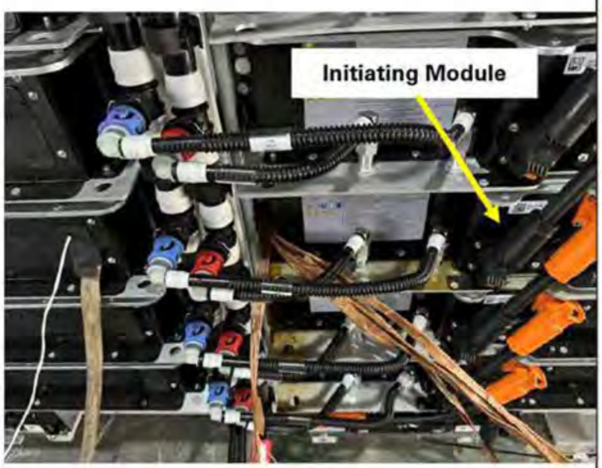
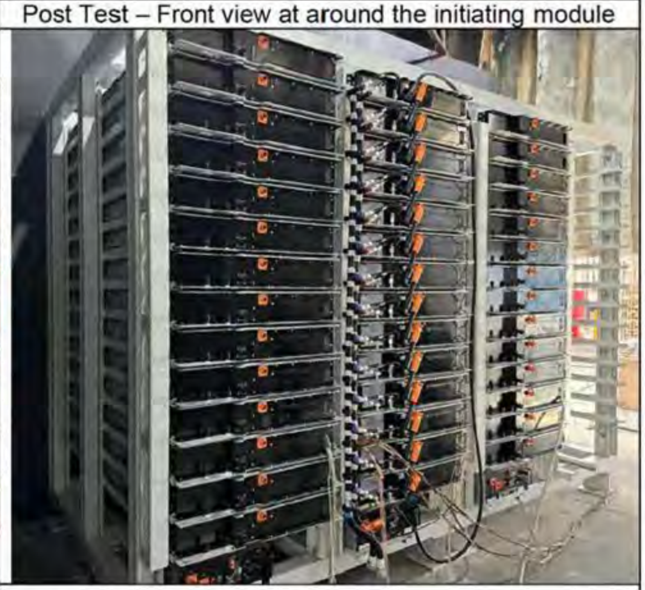
---

[7] Visual indication of vent was not observed but the sudden temperature dip was measured in the initiating cell surface according to data.

(g) Thermal Runaway Propagation (Cell #4)
[00:45:18]

(h) Thermal Runaway Propagation (pad right next to Cell #1)
[00:55:19]

(i) End of Video
[03:09:00]

	
Post Test – Front view of Initiating Unit	Post Test – Front view at around the initiating module
	
Post Test – View around components retaining coolant	Post Test – Front view of the whole rack on angle 45 °.

Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles - (*Pages **60** through **61***)

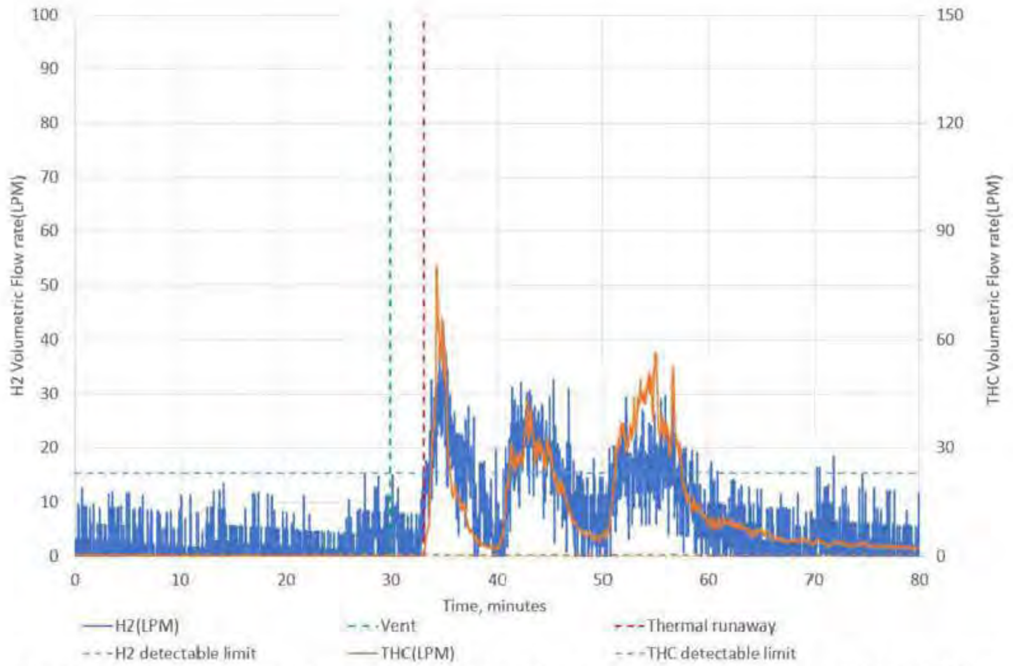


Figure F1. Volumetric flow rates of gases over the duration of the unit test (H2 and THC)

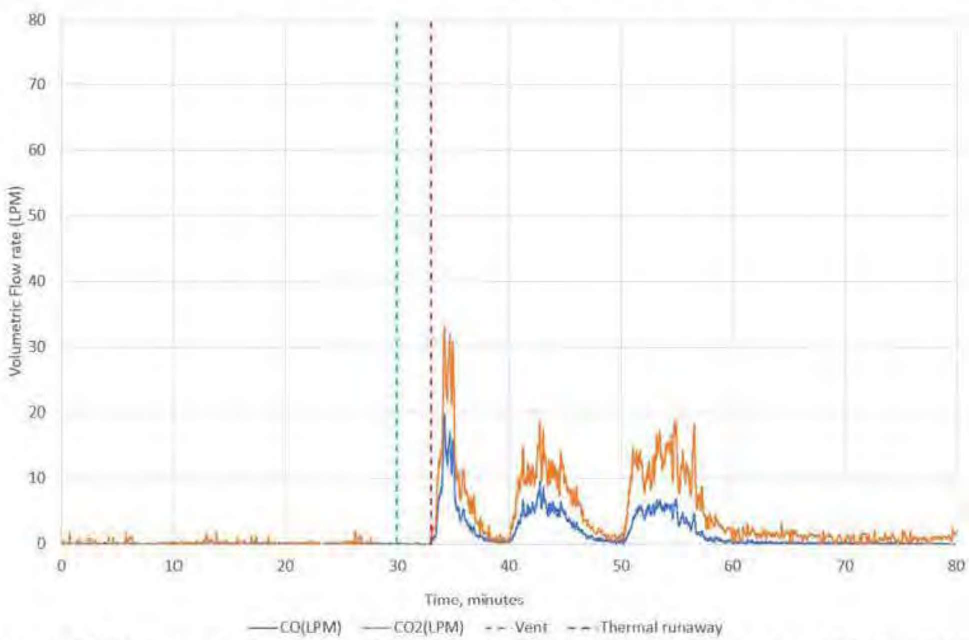


Figure F2. Volumetric flow rates of gases over the duration of the unit test (CO and CO2)

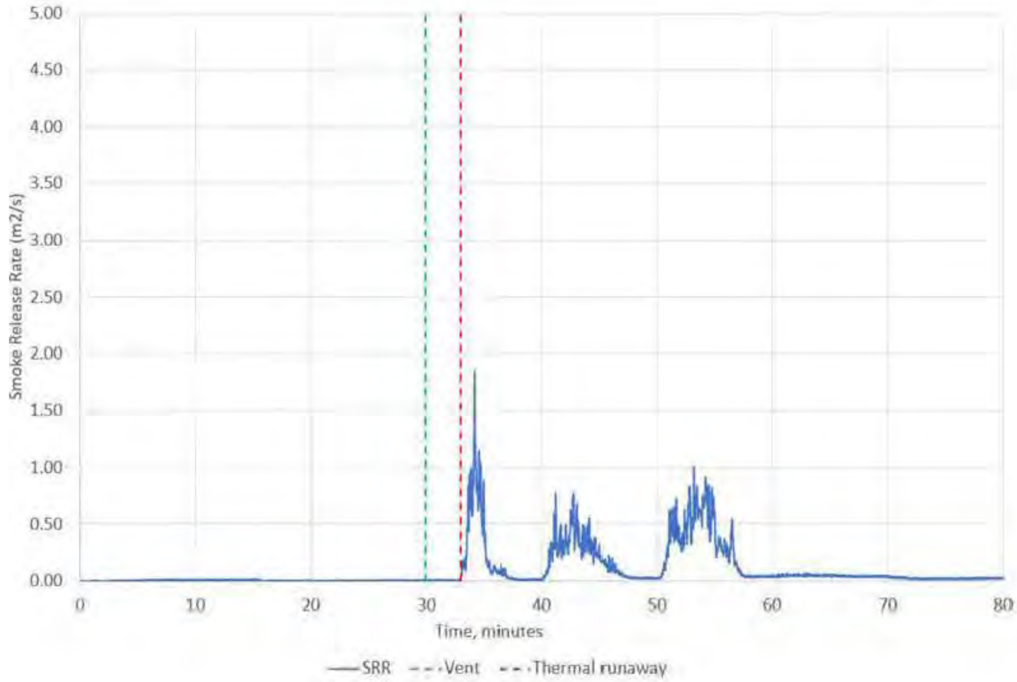


Figure F3. Smoke Release Rate

Attachment G: Certification Requirement Decision - (*Pages **62** through **63***)

CRD dated 2020-01-10 regarding the omission of FTIR provided below of for reference.

UNDERWRITERS LABORATORIES INC. CERTIFICATION REQUIREMENT DECISION

This Certification Requirement Decision is prepared by UL LLC. It is normative for the applicable UL Product Certification Program(s); however, it is currently not part of the UL Standard(s) referenced below.

Product Category (CCN): AACD
Standard Number: UL 9540A
Standard Title: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Edition Date: November 12, 2019
Edition Number: 4
Section / Paragraph Reference: 8.12, 8.13, 9.24, 9.25, 10.3.13
Subject: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test.

DECISION:

8.2.1~~3~~2 The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.

8.2.1~~2~~3 The hydrocarbon components of the ~~V~~vent gas composition may additionally ~~shall~~ be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or an equivalent gas analyzer~~,~~. ~~and v~~Velocity and temperature measurements respectively shall be obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.

9.2.24 The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct as outlined in 8.2.10. The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor. ~~Gas composition shall be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), or equivalent gas analyzer.~~ Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.

9.2.25 The hydrocarbon content of the vent gas ~~shall~~ may additionally ~~also~~ be measured using ~~flame ionization detection.~~ a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), or equivalent gas analyzer

10.3.13 The composition of BESS unit vent gases shall be measured as outlined in Section 9.2.24. The hydrocarbon content may additionally be measured as outlined in accordance with 9.2.25 ~~using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), total hydrocarbon analyzer, and hydrogen analyzer~~. The gas composition sampling port shall be located in the ceiling jet, 25-mm (1-in) below the ceiling

RATIONALE FOR DECISION:

In the 4th edition of UL 9540A, there is redundancy in the two measurement methodologies used to characterize the volume of flammable gas released during module and unit level testing (Flame Ionization Detection (FID) and Fourier Transform Infrared Spectroscopy (FTIR)). Both FTIR and FID were developed as required measurements for module and unit level testing in the first three editions of UL 9540A before data existed that enabled an understanding of the typical compositions of battery gas. Both FID and FTIR were specified as requirements because it was not clear that FID alone would provide an adequate characterization of all flammable gases released by batteries in thermal runaway. Therefore, FTIR was first intended to provide a means to quantify non-hydrocarbon flammable gases as well as to serve as a backup for FID measurement. FTIR, to a lesser degree, was also identified as a potential backup or improvement for CO and CO_2. Experience has demonstrated that an improvement to CO and CO_2 measurement is not necessary and a backup to non-dispersive infrared spectroscopy (NDIR) measurement has not been needed. Therefore, the FTIR will remain in the standard but as an optional additional measurement method.

In addition, hydrogen is measured with a hydrogen specific sensor, because neither FID or FTIR are capable of measuring hydrogen.

The list of equipment in Table 1 demonstrates overlap in the methodologies used for gas measurement.

Table 1 – Gas measurement equipment for fire and explosion hazards

Gas Hazard	**Measurement Equipment**
Hydrocarbons	1. Total unburned hydrocarbons by flame ionization detector (FID) 2. Individual components by Fourier Transform infrared spectrometry (FTIR)
Carbon monoxide (CO), Carbon dioxide (CO_2)	1. Individual components by non-dispersive infrared spectrometry (NDIR) 2. Individual components by FTIR
Hydrogen	1. Hydrogen sensor

UL Solutions

Safety. Science. Transformation.™

Date : 2025-06-05

Mr. Kim, Jinman

Company: LG Energy Solution, Ltd.
Address: 188, Munji-ro, Yuseong-gu, Daejeon 34122 KR

Our Reference:	E528302-20250226-Vol.3. Sec.1
Project No.	4791777103
Subject:	ANSI/CAN/UL9540:2020 Letter Report for Model LINK-FDMEPNCN

.
Dear Mr. Kim, Jinman

We hereby provide product evaluation report for the subjected model above against UL standard following:

ANSI/CAN/UL 9540:2025, Energy Storage Systems and Equipment, Edition 3, Revision Date 03/07/2025

This report acts as a supplementary information of subject product above and is only valid in conjunction with UL File No. E528302-20250226-Vol.3. Sec.1.

Please feel free to contact us if there is any question.
Thank you for your cooperative work.

Sincerely,

Byung Ho Lee
Senior Project Engineer

Reviewed by,

Henry Oh
Engineering Leader

UL Solutions | UL Korea, Ltd
26th FL, Gangnam Finance Center, 737
Yeoksam-dong, Gangnam-gu, Seoul 135-984 Korea
W: UL.com

Test Report issued under the responsibility of:

TEST REPORT **ANSI/CAN/UL 9540:2025** **Energy Storage Systems and Equipment, Edition 3, Revision Date 03/07/2025**

Report Number.............................. :	**Supplementary for E528302-20250226-Vol.3. Sec.1**
Date of issue.................................. :	**2025-06-05**
Total number of pages .... :	**61 pages**
Name of Testing Laboratory preparing the Report .... :	**UL**
Applicant's name .... :	**LG Energy Solution, Ltd.**
Address.. :	188, Munji-ro, Yuseong-gu, Daejeon 34122 KR
Test specification:	
Standard .... :	ANSI/CAN/UL 9540:2025, Energy Storage Systems and Equipment, Edition 3, Revision Date 03/07/2025
Test procedure .... :	WTDP
Non-standard test method .... :	N/A
Test Report Form No. .... :	ANSI/CAN/UL 9540:2025_TRF
Test Report Form(s) Originator .... :	UL
Master TRF .... :	Dated 2025-03-31

General disclaimer:

This report is valid only in conjunction with UL File No. E528302-20250226-Vol.3. Sect.1. with TestRecord No.4.

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of UL. The authenticity of this Test Report and its contents can be verified by contacting the UL, responsible for this Test Report.

Test item description........................:	Energy Storage Equipment Subassemblies – DC ESS
Trade Mark..:	LG Energy Solution
Manufacturer ....:	LG Energy Solution, Ltd.
Model/Type reference.......................:	LINK-FDMEPNCN
Ratings..:	See model differences below.

List of Attachments (including a total number of pages in each attachment):
(See the list of referenced documents)
N/A

Summary of testing:

Tests performed (name of test and test clause):	**Testing location:**
Sec. 30 Normal Operations Test[1)] Sec. 32 Dielectric Voltage Withstand Test[1),3)] Sec. 33 Impulse Test[1),3)] Sec. 34 Equipment Grounding and Bonding Test[1)] Sec. 35 Insulation Resistance Test[1),3)] Sec. 36.2 Electrostatic discharge[1)] Sec. 36.3 Radio-frequency electromagnetic field[1)] Sec. 36.4 Fast transient/burst immunity[1)] Sec. 36.5 Surge immunity[1)] Sec. 36.6 Radio-frequency common mode[1)] Sec. 36.7 Power-frequency magnetic field[1)] Sec. 36.8 Operational verification[1)] Sec. 38 Leakage Tests[1)] Sec. 40.1 Wall mount fixture/test[1),*] Sec. 41.2 Outdoors installations subject to moisture exposure[3)] Sec. 41.3 Outdoor installation in marine environments[2)] Note: Representative samples were used for performing tests above. Superscript indicates specific testing location. * Section 34. Wall Mount Fixture/Support Structure/Handle Test of ANSI/UL1973 was applied.	1) ONE Energy Solution Inc. 787-21 Dureungyuri-ro Ochang-eup Cheongwon-gu Cheongju-si Chungcheongbuk-do 28107 Republic of Korea 2) Korea Marine Equipment Research Institute 35 Mieumsandan5-Ro,Gangseo,Busan,46744,KR 3) Korea Marine Equipment Research Institute 5 Techno saneop-ro 55beon-gil Nam-gu,Ulsan,Ulsan,44776,KR

Summary of compliance with National Differences (List of countries addressed):
U.S. only.

☒ **The product fulfils the requirements of ANSI/CAN/UL 9540:2025, Energy Storage Systems and Equipment, Edition 3, Revision Date 03/07/2025**

Copy of marking plate:

The artwork below may be only a draft. The use of certification marks on a product must be authorized by the respective NCBs that own these marks.

LG Energy Solution	
System	
System Model Name	LINK-FDMEPNCN
ESS Type	DC ESS
M-LINK Model Name [M]	☐ A ☐ B ☐ F ☐ G
E-Panel Model [EPN]	☐ 2AR ☐ 2BL ☐ 2CL
	☐ 2DR ☐ 2FL
	☐ 2JR ☐ 2KL ☐ 2LL
CP-rate [C]	1 (0.25CP)
M-LINK Quantity [N]	☐ 1 ☐ 2 ☐ 3
Battery Type	Lithium Ion
Voltage range	DC: 1,134 V ~ 1,499.4 V
Energy	1.704 MWh (N=1), 3.408 MWh (N=2), 5.112 MWh (N=3)
Max. Current	375.66 A (CN=11), 751.32 A (CN=12), 1,126.98 A (CN=13)
Max. Power	0.426 MW (CN=11), 0.852 MW (CN=12), 1.278 MW (CN=13)
Weight	14.5 ton (N=1), 29 ton (N=2), 43.5 ton (N=3)
Operating Temperature	-30 °C ~ 50 °C (-22 °F ~ 122 °F)
Degree of Protection	IP55
Altitude	≤ 2,000 m
E-Panel	
Dimension (W * D * H)	2,570 * 750 * 2,746 mm
Supply ratings	∿ 480 Vac, 3Ph/3W, 60 H∿ FLC 29 A
Rated voltage	⎓ DC 1500 V
Rated current	⎓ DC 1200 A
Rated short time withstand current	100 kA 1s (150 kA 50ms)
M-LINK	
Dimension (W * D * H)	2,100 * 2,570 * 2,746 mm
Chiller Capacity	7 kW (Cooling), 3 kW (Heating)
HVAC Capacity	2 kW (Cooling), 1 kW (Heating)
SKID	
Dimension (W * D * H)	7,170 * 2570 * 150 mm
Drain Tank Storage Capacity	75 L (Min.) * 3 ea

Marine Environment Available.
This Equipment meets the Unit Level Performance Criteria of UL9540A.

Company address
Tower1, 108, Yeoui-Daero, Yeongdeungpo-gu
Seoul, 07335, Republic of Korea

System QR

System Num ex. ETD12345

LISTED E528302

Refer to E528302-20250226-Vol.3. Sec.1

Test item particulars...:	N/A
Classification of installation and use.......................: **Supply Connection..:**	Commercial and Industrial application. Auxiliary AC 480V, 60Hz, 3p3w / Main DC 1500V
Possible test case verdicts:	
- test case does not apply to the test object...........:	N/A
- test object is deemed to meet the requirement....:	P (Pass)
- test object is deemed not to meet the requirement ....:	F (Fail)
- test object is subjected to get further evaluation :	C (Conditional Acceptance)
General remarks:	
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report. **Throughout this report a ☐ comma / ☒ point is used as the decimal separator.**	

General product information and other remarks:

The product is Energy Storage Equipment Subassemblies - DC ESS, called to be DC-LINK, consisting of one(1) E-PANEL, and one(1) to three(3) M-LINK(s) on the skid.

Model Difference(s):

Model LINK-FDMEPNCN where M = can be A, B, F, or G representing LINK-S-MLK-A, LINK-S-MLK-B, LINK-S-MLK-F, or LINK-S-MLK-G correspondingly, EPN = can be 2AR, 2BL, 2CL, or 2DR, 2FL, 2JR, 2KL, or 2LL representing subsystem E-PANEL name of EPNL_1200A, EPNL_1200B, EPNL_1200C, EPNLNN_1200A, EPNLNN_1200C, EPNLTF_1200A, EPNLTF_1200B, or EPNLTF_1200C correspondingly, where C = 1 reflecting CP-Rate value of 0.25, and N = 1, 2, or 3 representing number of M-LINK(s) in DC-LINK system.

When system model obtains EPN = 2BL, it shall be used with another DC LINK model due to non-existence of BSC (Industrial PC).

When system model obtains M = B, EPN shall be either 2DR or 2FL.

When system model obtains M = F or G, EPN shall be 2JR, 2KL or 2LL.

Rating(s):

Item	Specification		
Max. CP Rate	0.25		
Number of M-LINK	1	2	3
Number of Total Battery Racks	2	4	6
Energy, MWh	1.704	3.408	5.112
Capacity, Ah	2320	4640	6960
Max. Charge/Discharge Power, MW	0.426	0.852	1.278
Operating Voltage, Vdc	1134 – 1499.4	1134 – 1499.4	1134 – 1499.4
Max. Current. A dc	375.66	751.32	1126.98
Weight, t	14.5	29.0	43.5
System Model Names (applicable examples)	LINK-FDA2AR11, LINK-FDA2BL11, LINK-FDA2CL11, LINK-FDB2DR11, LINK-FDB2FL11, LINK-FDB2DR11, LINK-FDB2FL11, LINK-FDF2JR11, LINK-FDF2KL11, LINK-FDF2LL11, LINK-FDG2JR11, LINK-FDG2KL11, LINK-FDG2LL11	LINK-FDA2AR12, LINK-FDA2BL12, LINK-FDA2CL12, LINK-FDB2DR12, LINK-FDB2FL12, LINK-FDB2DR12, LINK-FDB2FL12, LINK-FDF2JR12, LINK-FDF2KL12, LINK-FDF2LL12, LINK-FDG2JR12, LINK-FDG2KL12, LINK-FDG2LL12	LINK-FDA2AR13, LINK-FDA2BL13, LINK-FDA2CL13, LINK-FDB2DR13, LINK-FDB2FL13, LINK-FDB2DR13, LINK-FDB2FL13, LINK-FDF2JR13, LINK-FDF2KL13, LINK-FDF2LL13, LINK-FDG2JR13, LINK-FDG2KL13, LINK-FDG2LL13

For more details, please refer to Nameplate marking and UL File No. E528302-20250226.

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict

	CONSTRUCTION		**P**
7	Non-Metallic Materials		P
7.1	Polymeric materials employed for enclosures, or parts of enclosures for ESS shall comply with (a) and (b) below: a) The enclosure requirements outlined in UL 746C, Path III of the Enclosure Requirements, or CSA C22.2 No. 0.17; and b) For BESS, the enclosure shall be evaluated to UL 9540A Unit Level testing and meet the unit level performance criteria. *Exception: Equipment of a multi-part ESS that complies with the enclosure requirements in the appropriate standard for that equipment is not required to comply if the equipment enclosure is determined suitable for the intended environmental conditions that the ESS will be exposed to.*	Metal enclosure	N/A
7.2	The following factors in (a) – (e) shall be taken into consideration when an enclosure employing nonmetallic materials is being judged. For a nonmetallic enclosure, all of these factors are to be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief test. Suitability to factors (a) – (e) below shall be determined by the tests of this Standard or UL 746C, or the enclosure tests of critical component standards such as UL 1973 or UL 1971, if the enclosure for the critical component is covered under that standard. a) Resistance to impact; b) Crush resistance; c) Abnormal operations; d) Severe conditions; and e) Mold-stress relief distortion.	Metal enclosure	N/A

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
7.3	In addition to the items in 7.2, polymeric enclosures shall have the following properties: a) Minimum 5 VA flame rating, or the enclosure complies with the 127 mm (5 inch) Flame test of UL 746C, and for large surface areas having for any single unbroken section, a projected surface area greater than 0.93 m2 (10 ft2) or a single linear dimension greater than 1.83 m (6 ft) require flame spread testing per the Enclosure Flammability – Large Surface Area Considerations test of UL 746C; b) Insulation material properties per the Material Property Considerations table of UL 746C; c) Compliance with the Strain-Relief Test after Mold Stress-Relief Distortion of UL 746C if serving as a securement means for a strain relief; d) Compliance with the Ultraviolet Light Exposure test of UL 746C if exposed to UV rays in the end use; e) Compliance with the Water Exposure and Immersion test of UL 746C if exposed to rain in the end use; and f) Compliance with the Conduit Connections in the Enclosure Requirements table of UL 746C if mounting conduit connections.	Metal enclosure	N/A
7.4	The requirements in 7.3 do not apply to a nonmetallic part that forms part of the enclosure under any one of the following conditions in accordance with UL 94 or CSA C22.2 No. 0.17: a) The part covers an opening that has no dimension greater than 25.4 mm (1 in) and the part is made of a material Classed as V-0, V-1, V-2, or HB; b) The part is made of a material Classed V-0, V-1, V-2, or HB and covers an opening which does not give access to the user, when the part is removed, to live parts involving a risk of fire, electric shock, or electric energy-high current levels or moving parts; c) The part covers an opening that has no dimension greater than 101.6 mm (4 in) and the part is made of a material Classed as V-0, V-1, V-2, or HB, and there is no source of a risk of fire closer than 101.6 mm (4 in) from the surface of the enclosure; or d) The part is made of a material Classed V-0, V-1, V-2, or HB and there is a barrier or a device that forms a barrier made of a material Classed V-0 between the part and a source of a risk of fire. *Exception: A part of a component is not required to be Classed V-0, V-1, V-2, or HB when it complies with the flammability requirements applicable to the component.*	Metal Enclosure	N/A

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
7.5	Materials employed as electrical insulation in the ESS shall be resistant to deterioration that would result in an electrical shock, fire or other safety hazard. Insulation materials that are in direct contact with or close proximity to hazardous live parts in accordance with Figure 6.1 of the Material Property Considerations table in UL 746C or CSA C22.2 No. 0.17, shall additionally meet the insulation criteria outlined in either standard unless employed as part of a component that has been evaluated to a component standard that has comparable safety criteria. Insulated wiring is subjected to the requirements outlined in Section 11. *Exception: As an alternative, polymeric materials used to support live parts shall comply with the Control of Fire Spread in PS2 Circuits requirements or the Control of Fire Spread in a PS3 Circuit requirements in UL 62368-1/*CSA C22.2 No. 62368-1*, Clauses 6.4.5 or Clause 6.4.6 as applicable.*	Complied. Recognized Components were used.	P
7.6	Gaskets and Seals relied upon for safety, shall be determined suitable for the environmental conditions and chemical substances they are anticipated to be exposed to in their end use.	Complied. Recognized Components were used.	P
7.7	Compliance with 7.6 for gaskets and seals relied upon to prevent ingress of moisture into the enclosure, can either comply with the Gaskets Tests Clause of UL 50E/CSA C22.2 No. 94.2 or comply with UL 157 or ASTM D412 for the anticipated exposures.	Complied along with IPX5 testing to prevent ingress of moisture into the enclosure.	P
8	Metallic Enclosures and Parts Resistance to Corrosion		P
8.1	Metallic enclosure parts for BESS shall be of non-combustible materials as defined in this Standard. *Exception: Metallic enclosures of BESS that do not meet the definition of non-combustible, shall be evaluated to UL 9540A Unit Level testing and meet the performance level criteria for the unit level test.*	Complied.	P
8.2	Metallic enclosure parts that provide physical protection to ESS components or prevent access to hazardous ESS components shall have sufficient strength to provide physical protection and shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion resistance can be found in UL 50E/CSA C22.2 No. 94.2, or the applicable parts of the ISO 12944 standard series. Metallic enclosures of parts of a multi-part ESS that meet the enclosure requirements of their component standard such as UL 1741 and UL 1973 are considered to comply with these requirements without further evaluation.	Complied. Hazardous parts are not user-accessible.	P

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Clause	Requirement + Test	Result - Remark	Verdict
8.3	Conductive parts with dissimilar metals in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Figure F1 of Annex F shall be avoided. Use of coatings to prevent corrosion such as silver are methods to meet this requirement.	Complied.	P
9	Enclosures and Guarding of Hazardous Parts		P
9.1	The enclosure(s) of an ESS shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its transportation, installation and intended use. The enclosure strength shall be determined and specified to demonstrate compliance. The enclosure strength requirements outlined in UL 50, UL 1741, IEC 62477-1, UL 2755, ISO 1496-1 or equivalent standard shall be applied to demonstrate compliance. *Exception: For smaller systems that are less than or equal to 50 kWh, the enclosure strength may be evaluated to the enclosure requirements of this Standard and tested in accordance with the applicable tests of Section 40.*	Complied.	P
9.2	Rack assemblies complying with UL 2416 are a means to meet this criteria for internal support structures of the ESS if the assembly is used within its load ratings. See also 10.2 regarding walk-in units and modifications to load bearing walls.	Non walk-in unit. The support structure test was conducted according to ANSI/UL1973 for rechargeable Li-ion Battery Rack frame structure.	N/A
9.3	Openings in the enclosure of an ESS shall be designed to prevent inadvertent access to hazardous parts. Compliance shall be determined in accordance with the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, Clause 12 of IEC 60529 or CSA C22.2 No. 60529, for a minimum IP rating of IP2X and CSA C22.1, the Enclosure Selection Table for Nonhazardous Locations, with consideration of the end use installation. *Exception: An ESS intended for restricted access locations need not meet the accessibility criterion if permanent warning markings for service and other personnel having access to the system are provided directly on the system. Protection from access to hazardous live parts in restricted locations shall be in accordance with Article 110 of NFPA 70, or Sections 2 and 36 of the CSA C22.1, or Section 124 of IEEE C2, as applicable. Suitable cautionary warnings and signage for identifying exposed hazardous voltage circuits shall be provided for protection of service personnel.*	IP5X enclosure	P

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Clause	Requirement + Test	Result - Remark	Verdict
9.4	In service access areas, bare parts of hazardous voltage circuits, shall be located or guarded so that accidental shorting across circuits at opposite polarity, to ground, to SELV circuits or communications circuits, that could be caused by items such as, but not limited to, tools or test probes used by service personnel, is unlikely.	Hazardous live parts are covered by additional safety guards to prevent direct access and accidental shorting during service.	P
9.5	Enclosures of systems and components of systems located where they will be subject to exposure to water and other elements shall be rated for the level of intended exposure as outlined in Table 110.28 of Article 110 of NFPA 70, or Section 2 of CSA C22.1 or for the ingress protection rating of IPX3 or higher as outlined in IEC 60529 or CSA C22.2 No. 60529 if using as IP rating. Installation instructions shall indicate restrictions with regard to limiting ingress from the environment based upon the enclosure rating.	IPX5 enclosure	P
10	General Electrical Safety of Systems and Additional Requirements for Walk-in Units		N/A
10.1	The instructions shall include measures and procedures for worker safety in, on and adjacent to the ESS according to NFPA 70E and CSA Z462, and Section 2 of CSA C22.1, and in accordance with this Standard.	Safety instructions were provided along with manuals.	N/A
10.2	Walk-in unit enclosures shall have suitable mechanical load ratings for equipment installed within the enclosure, including maximum number of persons who may enter the enclosure when all of the equipment is installed.	Non Walk-in unit	N/A
10.3	Shipping container type enclosures with cutouts or other modifications to support walls that may affect their load bearing performance shall be re-evaluated to ASTM D4169 for ability to handle the intended loads post modification.		N/A
10.4	The enclosures for outdoor walk-in units shall not exceed 16.2 × 2.6 × 2.9-m (53 × 8.5 × 9.5-ft) high, not including HVAC and related equipment that may be secured to the exterior of the enclosure. A walk-in enclosure exceeding these dimensions are subjected to indoor installation criteria in accordance with the applicable codes.		N/A
10.5	If the walk-in unit is provided with an explosion venting system, it shall comply with the applicable requirements in 24.5.		N/A
10.6	Where persons can access the hazardous areas within a walk-in unit, procedures for safe entry into and exiting the system shall be provided in the instructions provided with the ESS. Means, such as, but not limited to a placard(s) and lock(s), shall be provided to prevent unauthorized persons from entering these hazardous areas. See 46.17.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
10.7	Personnel doors of walk-in units shall be designed to prevent persons from becoming trapped within the unit and shall be able to be opened from the inside without use of a tool or key. Door(s) intended for entrance to, and egress from a walk-in unit, shall open in the direction of egress and provide a clear width of at least 80 cm (32 in) and clear height of at least 183 cm (72 in) based on the dimensions specified in the ICC IBC. Each egress door shall be marked in accordance with 45.19 and the line-of-sight to an exit sign shall not be interrupted. Any doorway or passage that might be mistaken for an exit shall be marked in accordance with 45.19 or with an indication of its actual use. See also 45.18		N/A
10.8	Work space dimensions and requirements within an ESS, provided with walk-in enclosures, shall be in accordance with NFPA 70, or CSA C22.1, or in accordance with IEEE C2 as applicable to where the system is installed. The space requirement shall also provide for appropriate arc flash safety under specified personal protective equipment (PPE). See 45.13.		N/A
10.9	Areas of access to walk-in units shall be designed to prevent tripping, slipping or falling when persons enter, exit or while within the unit. Surfaces and parts within a walk-in unit shall be designed to prevent inadvertent hazards to personnel within the enclosure through appropriate guarding, electrical and thermal insulation methods and cautionary warnings and signage in accordance with this Standard. See 10.7 and 45.16.		N/A
10.10	Protection against contact with hazardous voltage parts in the ESS, including walk-in enclosures, shall be in accordance with 9.3 or through the use of guarding to prevent access with cautionary warnings and signage where only qualified personnel are allowed access. Entrances to walk-in enclosures that contain exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter. See also 12.2 with regard to disconnect criteria for servicing, etc. and 45.13 and 45.16. The enclosures of walk-in units shall be provided with grounding in accordance with 14.4.		N/A
10.11	The type of protection equipment to be provided for arc flash hazards shall be determined by an arc flash risk assessment conducted according to NFPA 70E and CSA Z462. The arc flash assessment results shall be labeled on the ESS. The assessment shall determine: a) The arc flash incidental energy level; b) The arc flash boundary, restricted approach boundary; and c) The required arc flash personal protective equipment.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
10.12	The boundary for an unprotected arc flash shall be considered one that has an arc rating above 5 J/cm2 (1.2 cal/cm2) incident energy level (e.g. can cause a second degree burn to unprotected skin) per NFPA 70E and CSA Z462.		N/A
10.13	Energy storage system enclosures that can be fully entered by persons such as walk in units, shall be designed to automatically provide mechanical ventilation using 100 % outdoor air when anyone is working within the enclosure. The minimum amount of ventilation air shall be 5.1 L/s/m2 (1 cf/min/ft2).		N/A
10.14	Electrical circuits that are an integral part of the ESS including those that are part of a walk-in enclosure including lighting, controls, power, HVAC, emergency lighting, alarm circuits, and the like shall comply with the appropriate requirements for the type of equipment and the specific application within the ESS.		N/A
10.15	Electrical equipment including electrical equipment that is located in the walk-in enclosure in areas that will be subject to condensation, or the effects of condensation from equipment or systems that are provided with and installed in, on or around the ESS enclosure, shall be suitable for outdoor use or suitably protected against contact with water and protected against unsafe conduction of hazardous voltages to personnel via water as a conduction path.		N/A
10.16	Lighting shall be provided in enclosed working spaces associated with the ESS. The lighting source shall provide at least 100 lux and controlled only by manual means. Lighting within an ESS including lighting within a walk-in enclosures shall be installed in accordance with Article 410 of NFPA 70 or Section 30 of CSA C22.1 as applicable to the system where the system is installed.		N/A
10.17	Where there is more than one source of energy input to the ESS, the ESS shall be provided with information and markings to indicate which disconnect device or devices are required to be operated to completely isolate the equipment.		N/A
10.18	Protection against lightning surges shall be provided in accordance with the requirements of NFPA 70 or CSA C22.1, or IEEE C2 as applicable to where the system is intended to be installed.		N/A
11	Wiring and Electrical Supply Connections		P
11.1	Wiring installed on the equipment, including internal wiring or supplied with the equipment for installation on-site, shall be insulated and acceptable for the intended purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected where the wiring is located.	Complied.	P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
11.2	Wiring methods and electrical supply connections of energy storage systems shall be in accordance with NFPA 70 or CSA C22.1, or IEEE C2 as applicable to where the system is installed. Energy storage systems which are considered evaluated pieces of equipment shall ensure the electrical supply connections comply with NFPA 70, CSA C22.1 or IEEE C2 as applicable to where the system is installed. Wiring methods for such evaluated pieces of equipment are encouraged to follow the aforementioned codes, but at a minimum shall comply with this Wiring and Electrical Supply Connections Section.	Complied. External cable connections were not in the scope of evaluation but following the provided installation manual shall comply the requirement.	P
11.3	An ESS shall have provision for connection of the system to an external wiring system consisting of: a) Wiring terminals or wiring leads; or b) A means for connection of cable or conduit in accordance with the codes in 11.2.	Complied. External cable connections were not in the scope of evaluation but following the provided installation manual shall comply the requirement.	P
11.4	A wiring terminal or lead that is supplied as a component of the ESS shall be rated and sized for connection to a field wiring conductor having an ampacity of no less than 125 % of the ac or dc current that the circuit carries during rated conditions and in accordance with the codes in 11.2.	Complied. External cable connections were not in the scope of evaluation but following the provided installation manual shall comply the requirement.	P
11.5	A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is to be connected, and shall not be smaller than 2.08 mm2 (14 AWG). A field-wiring lead shall not be less than 152.4-mm (6-in) long. *Exception No. 1: Communications cable may be less than 2.08 mm2 (14 AWG).* *Exception No. 2: Field wiring harness accessories supplied by the manufacturer and evaluated for use with the system.*	External cable connections were not in the scope of evaluation but following the provided installation manual shall comply the requirement.	P
11.6	Field-wiring compartments, in which branch circuit connections are to be made, shall: a) Permit the connection of the supply wires after the ESS is installed; b) Permit the connection to be introduced and connected easily and safely; and c) Be located so that the connections can be readily inspected after the ESS is installed.	External cable connections were not in the scope of evaluation but following the provided installation manual shall comply the requirement.	P
11.7	Internal wiring shall be routed, supported, clamped or secured in a manner that reduces the likelihood of excessive strain on wire and on terminal connections; loosening of terminal connections; and damage of conductor insulation. In safety critical circuits, for soldered terminations, the conductor shall be positioned or fixed so that reliance is not placed upon the soldering alone to maintain the conductor in position.	Complied.	P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
11.8	A hole by which insulated wires pass through the system enclosure or elements providing separation within the enclosure shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, to prevent abrasion of the insulation.	Complied.	P
11.9	Where multiple conductors are installed in parallel, they shall be installed in groups consisting of not more than one conductor per phase, neutral or ground so that the current in each group sums to zero. Where conductors pass through a metal opening, all conductors in a group shall pass through the same opening.	Complied.	P
12	General Electrical Equipment		P
12.1	Replaceable fuses shall have a fuse replacement marking with the fuse ratings located adjacent to each fuse or fuse holder, or on the fuse holder, or in another location provided that it is obvious to which fuse the marking applies. Where replaceable fuses with special characteristics such as time delay or breaking capacity are necessary, the type shall also be indicated. Information on proper fuse replacement of replaceable fuses shall also be included in the service manual instructions.	Complied.	P
12.2	Exposed hazardous voltage in an ESS shall be provided with a lockable manual disconnect to enable Lock-Out-Tag-Out (as required in NFPA 70E and CSA Z462) during servicing or for emergency procedures. The lockable manual disconnect shall have sufficient interrupt ratings, shall be accessible to the technician servicing the system and to first responders and shall be located as close to the exposed hazardous voltage conductors as possible. When the lockable manual disconnect is not provided directly on the system by the system manufacturer, the installation instructions shall indicate the type and ratings of the disconnect to be provided in the installation and how it is to be installed in accordance with NFPA 70E and CSA Z462. *Exception: A lockable disconnect is not required where it is infeasible based upon the design of the system (e.g. interspersed in the middle of a high voltage battery string, within a battery system, to segment the string into segments less than the minimum hazardous voltage).*	Complied.	P

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Clause	Requirement + Test	Result - Remark	Verdict
12.3	Fuses, circuit breakers and disconnect devices shall be rated for the application including fault current ratings, suitability for disconnect under load, etc., as applicable to the device and application in the system. The ESS shall be provided with short circuit protection within the system to mitigate hazards associated with a short circuit condition of the integral energy storage technology, including addressing the potential for additive fault currents when multiple battery systems are connected in parallel. This protection shall be provided as part of the energy storage technology or installed as a separate component within the ESS. Protection against overload and short circuits of external circuits shall use branch circuit rated protectors or electronic circuits evaluated for the purpose.	Complied.	P
12.4	Transformers installed as part of the ESS shall be of the dry type or type filled with a non-combustible dielectric medium. Such transformers shall be installed in accordance with the requirements of NFPA 70 or CSA C22.1, or in accordance with Section 15 of IEEE C2 as applicable to where the system is installed.	Used transformers are purposed to supply auxiliary power within the product. Subsystem evaluation standard requirements of transformers were applied for compliance.	P
12.5	With reference to 12.4, oil filled transformers shall be permitted for use in outdoor locations in accordance with the applicable local codes or utility requirements.	No oil filled transformers exist	N/A
12.6	Convenience receptacles provided for maintenance and servicing of the ESS shall be rated for outdoor use if the system is intended to be installed where the receptacle is exposed to the outdoor environment or outdoor environmental conditions.	Complied.	P
12.7	The inverter and other equipment connected to the output terminals of the battery or other storage device of the ESS shall be able to safely withstand the potential short circuit current from the storage device. The rated input short circuit current of the inverter and other equipment shall be equal to or greater than the rated output short circuit current of the battery or other energy storage mechanism. Compliance can be determined through evaluation of the output short circuit ratings of the energy storage mechanism (e.g. for the battery) as determined by testing in UL 1973. For equipment capable of providing an output short circuit current, the rating shall reflect the protection provided by any internal branch circuit protectors, including electronic circuit regulation, such as limitation of peak currents, inrush currents and time. An energy storage mechanism relying on a branch circuit protector installed on the output of the energy storage mechanism shall provide the maximum short circuit current from that device.	Complied at the subsystem level short-circuit tests in Combiner and System Transition Boxes (E-PANEL) and Rechargeable Li-ion Battery System(s).	P
13	Electrical Spacings and Separation of Circuits		P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
13.1	Electrical circuits within the ESS at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits or potential for arc flash (i.e. electrical spacings on printed wiring boards, physical securing of uninsulated leads and parts, etc.). Insulation suitable for the anticipated operating temperatures and voltages shall be used where spacings cannot be controlled by reliable physical separation.	Complied. Sufficient spacings and circuit separation were checked.	P
13.2	Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in Table 13.1 or as outlined in UL 62368-1/CSA C22.2 No. 62368-1, Clearances, Clause 5.4.2, and Creepage Distances, Clause 5.4.3. *Exception No. 1: The spacing requirements in UL 840, CSA C22.2 No. 62109-1, UL 62109-1, IEC 60664-1, or CSA C22.2 No. 0.2, shall be acceptable alternatives. The anticipated pollution degree and overvoltage category is determined by the design and application of the ESS assembly or subassembly under evaluation.* *Exception No. 2: Electrical spacings within components and parts of an ESS previously determined to comply with an appropriate safety standard for the equipment need not be evaluated.*	Complied.	P
13.3	There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a compound 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. 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. Materials employed as electrical insulation shall meet the requirements of 7.5.	Complied.	P
13.4	Conductors of circuits operating at different voltages shall be reliably separated from each other through the use of mechanical securements such as barriers or wire ties to maintain spacing requirements unless they are each provided with insulation acceptable for the highest voltage involved. An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different voltage.	Complied.	P
14	Insulation Levels and Protective Grounding		P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
14.1	Hazardous voltage circuits shall be insulated from accessible conductive parts and safety extra low voltage (SELV) circuits as outlined in 14.2 through the following: a) Basic insulation and provided with a protective grounding system for protection in the event of a fault of the basic insulation that complies with 14.3; b) A system of double or reinforced insulation; or c) A combination of (a) and (b).	Complied.	P
14.2	Safety extra low voltage (SELV) circuits, as defined in 6.40, that are insulated from accessible conductive parts through functional insulation only are considered accessible.	Complied.	P
14.3	Accessible non-current carrying metal parts of an ESS containing hazardous voltage circuits that could become live in the event of an insulation fault shall be bonded to the equipment ground terminal. The main grounding terminal shall be identified through use of grounding symbol, green coloring or word “GR” etc. to signify it as the equipment ground terminal and shall not be utilized for any other purpose than for the connection of the grounding and bonding conductors.	Complied.	P
14.4	The methods of protective bonding and grounding of an ESS shall be in accordance with Article 250 of NFPA 70 or Section 9 of IEEE C2 as applicable to where the system is located. When sizing the protective bonding and grounding wire, the rating and fault current path of all sources of supply connected to the equipment or system shall be considered. If used, grounding (bonding) braids used in the ESS or from the ESS to the grounding electrode shall comply with UL 467/CSA C22.2 No. 41, and sized according to the Grounding – Size of Terminal or Bonding Conductor requirements of UL 508A or CSA C22.1. In Canada, the methods of bonding and grounding an ESS shall be in accordance with Section 10 and 36 of CSA C22.1.	Complied. No Canadian deviation was considered.	P
14.5	Parts of the protective grounding system shall be securely fastened and provided with metal-to-metal contact that will ensure the continuity of the grounding system. All connections shall be secured against accidental loosening and shall ensure a thoroughly good connection. See 14.6, 14.7, and Section 33.	Complied.	P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
14.6	With reference to 14.5, when connecting conductive parts to be bonded, paint or coatings in areas of contact shall be removed or paint piercing lock washers shall be used with securement bolts or screws to provide good metal to metal contact. Thread-locking sealants, epoxies, glues, or other similar compounds, and solder alone shall not be used as a securement means as these are not considered reliable. In addition, rivets, hinges (unless metal-to-metal piano type hinges), and parts that may be removed as a result of servicing shall not be relied upon as connections for ensuring continuity of the protective grounding and bonding system. Bonding shall be achieved through the use of dedicated connections that are not utilized for other purposes.	Complied.	P
14.7	With reference to 14.5, methods of securement considered reliable and ensuring good metal-to-metal contact can consist of the following methods: a) Terminal blocks; b) Pressure connectors, grounding lugs and similar grounding and bonding equipment connectors; c) Fusion welding processes; d) Machine screw-type fasteners that engage not less than two threads or are secured with a nut; and e) Thread-forming machine screws that engage not less than two threads in the enclosure.	Complied.	P
14.8	For ESS greater than 100 V between conductors or to ground, the battery circuits can be ungrounded if the system is provided with a ground fault detector and indicator to monitor ground faults.	Complied. Additional investigation may require in upper system (AC ESS, etc.) regarding ground fault detector or indicator.	P
15	Safety Analysis and Control Systems		P
15.1	A safety analysis consisting of a hazard identification, risk analysis and risk evaluation including a safety analysis such as a failure modes and effects analysis (FMEA) that identifies critical safety components and circuits of the system, shall be conducted on the equipment forming the ESS and components of the ESS considering any interactions that provide a safety function. The analysis shall consider the compatibility of the parts of the ESS (e.g. battery system, charger, inverter, etc.) with regard to safety of the overall system. The analysis shall be performed by the manufacturer of the ESS or the entity that integrates the components that comprise the ESS, referred to as the energy storage system integrator. Guidance for analysis can be found in the following standards: a) IEC 60812; b) IEC 61025; and c) MIL-STD-882E.	Compliance was checked by technical assessment on the provided manufacturer's safety analysis documents that include hazard identification and risk assessment along with layered system and design failure effect analysis criticality analysis.	P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
15.2	Even when the major parts of the ESS are in compliance with their individual safety standards and they are being used within their ratings, it cannot be assumed that when the parts are connected together to form an ESS that the system is safe, without further analysis. The analysis of the ESS must evaluate whether or not the various parts of the ESS, even though determined to be safe individually, work compatibly with each other to prevent hazardous conditions from occurring. When conducting this analysis, it is important that the interaction of the various parts of the ESS be evaluated as noted in 15.1 to determine that there are no hazards introduced in the system as a result of their interaction. For example, communications delays between parts that could affect safety, surges or noise introduced from power conditioning devices or noise introduced from electrical connections, shall not affect the functionality or result in damage to these safety controls such as the battery management system (BMS), contactors or the energy storage management system.	Compliance was checked by reviewing supporting certificate files of UL1973 (BBFX2), and UL1741(QIAA2). Functional safety evaluation and construction/component review.	P
15.3	The safety analysis shall consider mechanical, thermal and other potential hazards associated with the ESS in addition to potential electrical hazards. This is especially critical when evaluating systems with hazardous kinetic energy, thermal ESS operating at hazardous temperatures and/or containing hazardous materials, and systems with parts under hazardous pressure levels. Analysis of flywheel systems shall be conducted on the bearing failure detection system, which shall detect signs of bearing failure before catastrophic bearing failure occurs. The bearing failure detection system shall be designed to initiate safety mechanisms within the flywheel control system to bring the flywheel to a safe state upon detecting signs of impending bearing failure. Analysis of flywheel systems shall also include the feedback and control for any active magnetic bearings or passive bearing used in conjunction with active unloading systems.	Compliance was checked by technical assessment on the provided manufacturer's safety analysis documents that include hazard identification and risk assessment along with layered system and design failure effect analysis criticality analysis.	P
15.4	Analysis of thermal ESS shall ensure that there is sufficient monitoring and control of pressure, thermal and fluid flow to ensure that the various parts of the system are maintained within their specifications for pressure temperature and fluid levels.	Electrochemical ESS (Rechargeable Li-ion Battery Systems were used in DC ESS)	N/A

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
15.5	Electrical and electronic controls of the ESS that are determined to be critical for safety shall comply with an appropriate safety standard for the control and used within their ratings. Electronics and software controls determined to be critical for safety are to be tested to verify electromagnetic immunity in accordance with Section 36 if this testing is not part of the functional safety standard requirements, and shall be evaluated for functional safety to one of the following sets of standards and safety ratings as applicable to the system: a) UL 991 and UL 1998; b) CSA C22.2 No. 0.8 (Function Class B requirements); c) The Annex for Requirements for Electronic Controls, Annex H of UL 60730-1 or CSA E60730-1 (Function Class B requirements); d) IEC 61508 (all parts) (minimum of Safety Integrity Level (SIL) "2" requirements for active protective devices with software controls); e) ISO 13849-1 and ISO 13849-2 (minimum of Performance Level (PL) "c" requirements for active protective devices with software controls); or f) ISO 26262 (all parts) (minimum Automotive Safety Integrity Level (ASIL) "C" requirements for active protective devices with software controls).	Considering safety analysis and system architecture, the primary protection and safety related electrical and electronic controls of product is done by multi-layered protective functions. The primary protection is done on battery management system on Rechargeable Li-ion Battery Rack(s). ISO13849-1 and ISO13849-2 were applied as the functional safety evaluation standard. In addition, chiller functional safety was conducted according to UL60730-1 Annex H	P
15.6	The required SIL, PL, or ASIL for a safety function shall be permitted to be reduced if the manufacturer provides additional safety analysis (e.g. Layer of Protection Analysis) showing that the required risk reduction level has been reduced by other measures within the ESS.	Compliance to PL.c [CAT2] target functional safety evaluation for critical protective functions for Rechargeable Li-ion battery system and Class B target functional safety evaluation for Chiller leak detection function. Layered protection for abnormal hazardous operation was implemented.	P

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Clause	Requirement + Test	Result - Remark	Verdict
15.7	When conducting the functional safety evaluation of electronic controls, the interaction of the various parts of the system need to be considered for their impact on each other. In particular, a number of disruptive interactions shall be considered in all cases. These interactions include: a) Noise, or other disturbances introduced into the system as a result of the interaction of the various ESS components such as between the PCS and the BMS of the battery or other electronic controls, shall be considered when evaluating the reliability of electronic and programmable electronic controls; b) The surge protection evaluation of the BMS and other electronic controls shall be sufficient to address potential surges that may be transmitted from the PCS or other equipment; c) Surge suppression protection shall be provided to protect the BMS or other electronic safety controls devices, if the control functionality of a BMS or other controls can be impacted as a result of this interaction; d) Parts such as power conditioning system (PCS) connected to the storage devices of the system (e.g. batteries), shall be able to safely withstand a fault current from the storage devices including current that is transmitted prior to operation of the short circuit protection; and e) Delays or other faults in communication signals between the various parts of the ESS that can impact safety.	Complied. Functional safety evaluation and verification of electromagnetic immunity tests meet the requirement.	P
15.8	Software and its associated hardware determined critical to safety that can be updated remotely shall meet the requirements outlined in Section 16, Remote Software Update Enabled ESS. Section 16.1 applies to software evaluated in accordance with UL 1998 and Section 16.2 applies to software evaluated in accordance with UL 60730-1 or CSA E60730-1.	Remote Software Update enabled.	P
16	Remote Software Update Enabled ESS		P
16.1	Critical and/or critical supervisory software (UL 1998)	Considering the functional safety evaluation according to ISO13849-1 and ISO13849-2, the compliance of remote software update was checked according to UL5500 requirement. The supervisory software is controlled under functional safety evaluation.	P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
16.1.1	The requirements in 16.1.2 – 16.1.7 apply when the manufacturer declares the ESS has critical and supervisory and related critical supervisory sections of software per UL 1998, and has the functionality to remotely update this software. NOTE 1: A software update occurs when software replaces or modifies the previous version by a new or the same version of the critical/supervisory sections of UL 1998 software. NOTE 2: These requirements are not intended to address cybersecurity.	Complied.	P
16.1.2	The critical/supervisory sections of UL 1998 software, intended to be updated, shall comply with UL 1998.	Complied.	P
16.1.3	User authorization is required prior to any remote update of critical/supervisory sections of UL 1998 software. NOTE: User authorization can be a one-time event. This one-time event may be when the homeowner of a residential ESS registers their ESS with the manufacturer, or downloads the application needed to remotely operate the residential ESS controls on their smart device (e.g. cell phone, tablet, etc.).	Complied.	P
16.1.4	The remote update of software shall occur when the ESS is in a risk addressed state.	Complied. Risk-addressed state is defined to be open circuit of DC power lines.	P

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Clause	Requirement + Test	Result - Remark	Verdict
16.1.5	The remote software update shall comply with UL 5500, with the following modifications: a) The device specific requirements for a remote update of software, per the requirements for Application of Received Software Download Package in UL 5500, shall occur when the ESS is in a risk-addressed state; and b) The bulleted items in the compliance criterion of the requirements for Documentation & Tracking in UL 5500 are replaced with the following: 1) Communication protocol (Compliance with the requirements for Establish Remote Connection, and the requirements for Download/Transmission in UL 5500); 2) Software update process (Compliance with the requirements for Hardware / Architecture / Software Download Package Compatibility Check, Application of Received Software Download Package, and Conclusion of Remote Software Update Process in UL 5500); 3) Identity and access management (Compliance with the requirements for Authentication, and Authorization in UL 5500); and 4) Validation measures (Compliance with the requirements for Remote Software Update Validation: General, Failure/Status Identification Detection, Response to Error Detection, and Software Download Package Version in UL 5500).	Remote Software Update functionality enables the software update to Battery Section Controller Software (BSC) and Rechargeable Li-ion Battery Rack System (RBMS). The compliance was checked by manufacturer specified documents and verification of remote software update validation measures.	P
16.1.6	The correct operation of the ESS safety functions shall be maintained after the critical/supervisory sections of software in accordance with UL 1998 software is updated.	Complied.	P
16.1.7	Compliance is checked by a functional test of a remote software update using the procedure outlined in Operational Verification of Remote Software Update Capability in 36.9 after implementing a remote software update. Consideration shall be made for a functional test (based on an impact analysis of the changes made to the software) to verify the proper operation of the ESS system protective control functions. NOTE: When determining which safety functions need to be verified after the update has been completed, consideration is to be given to the specific aspects of the software that have been updated.	Complied.	P
16.2	Class B software (UL 60730-1 or CSA E60730-1)	See the Sec. 16.1	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
16.2.1	The requirements in 16.2.2 – 16.2.8 apply when the manufacturer declares the ESS has Class B software in accordance with UL 60730-1 or CSA E60730-1, and has the functionality to remotely update this software. NOTE 1: An update occurs when software replaces or modifies the previous version of the Class B software, UL 60730-1 or CSA E60730-1 software. Additionally, an update occurs when the same version of Class B software, is replaced during the remote update process. NOTE 2: These requirements are not intended to address cybersecurity.		N/A
16.2.2	The Class B software of UL 60730-1 or CSA E60730-1 intended to be remotely updated, shall comply with the requirements for Controls Using Software in UL 60730-1 or CSA E60730-1.		N/A
16.2.3	The remotely actuated control function, including the software update function, shall comply with the requirements for Remotely Actuated Control Functions in UL 60730-1 or CSA E60730-1. With respect to transmission faults, Note 1 of Clause H.11.12.4.1.3.1, Transmission, is considered normative. NOTE 1: A remotely actuated control function is a function providing any operation by control devices through external means. This includes, but is not limited to: a) The use of communication lines/protocols; b) IR/RF transmission; or c) All combinations of (a) – (b) above via Internet using, for example modems, portable telephones, etc. NOTE 2: Remote software updates require minimum or no interaction with the ESS. Software updates are received remotely without the use of external hardware such as a USB, SD card, etc.		N/A
16.2.4	Remotely actuated control functions may be connected to separate, independent devices, which may themselves contain control functions or provide other information. Any data exchange between these devices shall not compromise the integrity of the Class B control function.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
16.2.5	User authorization is required prior to any remote update of Class B software, UL 60730-1 or CSA E60730-1. This will be evaluated in accordance with UL 60730-1 or CSA E60730-1, Clause H.11.12.4.4.3. NOTE: User authorization can be a one-time event. This one-time event may be when the homeowner registers their residential ESS with the manufacturer, or downloads the application needed to remotely operate the ESS on their smart device (e.g. cell phone, tablet, etc.).		N/A
16.2.6	The remote update of software shall occur when the ESS is in a risk addressed state.		N/A
16.2.7	The correct operation of the ESS's safety functions shall be maintained after the Class B software is updated per UL 60730-1 or CSA E60730-1.		N/A
16.2.8	Compliance is checked by a functional test of a remote software update using the procedure outlined in Operational Verification of Remote Software Update Capability in 36.9 after implementing a remote software update. Consideration shall be made for a functional test (based on an impact analysis of the changes made to Class B software) to verify the proper operation of the ESS protective control functions. NOTE: When determining which safety functions need to be verified after the update has been completed, consideration is to be given to the specific aspects of the software that have been updated.		N/A
17	Remote Controls		N/A
17.1	Energy storage systems which have the ability to be controlled and operated remotely shall be provided with an accessible means to disconnect the system from the remote control for maintenance or other local servicing of the system. The remote control disconnect shall either be provided on the system or instructions in the installation manual shall provide the location and type of disconnect to be provided in the end use installation. The use of a remote control systems shall not lead to an unsafe condition as determined by the system safety analysis and shall not be able to override local safety controls. If the remote control disconnect is to be provided as part of the installation (not built into the ESS), the instructions shall include information on the electrical connections including means to prevent the disconnect from being overridden by the remote control system.	Remote control related evaluation will be required in upper level system (e.g. AC ESS)	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
17.2	Remote disconnect controls such as Emergency Power Off (EPO) buttons shall be marked to clearly indicate what system or part of the system they control. Remote disconnect control such as EPOs that disconnect and de-energize the complete ESS, need to not be marked in this manner.	EPO buttons are clearly indicated but remote disconnected control related topic will be required in upper level system (e.g. AC ESS)	N/A
18	Communication Systems		P
18.1	General		P
18.1.1	Instructions for installation and operation of the ESS shall identify the communication protocols used by the ESS for communication with external systems intended to be connected to the ESS. Energy storage system components and subassemblies that need to communicate with each other to ensure safe operation of the system, shall utilize harmonized communication protocols, and evaluation of the compatibility of these interconnecting communication systems shall be included in the safety analysis of Section 15.	Complied by construction review and communication system diagrams. The sufficient safety analysis on internal communication among multiple system systems were conducted.	P
18.2	External warning communication system (EWCS)	Complied.	P
18.2.1	Electrochemical ESS using lithium-ion batteries as the storage mechanism that have an energy capacity of 500 kWh or greater shall be provided with an external warning communication system, as outlined in 18.2.2 – 18.2.6, that gives an advance notification to operators of a potential safety issue with the ESS.	External warning communication system (EWCS) were cleared provided and compliance to applicable requirements were checked.	P
18.2.2	The information inputs to the EWCS shall come from those devices in the ESS that can supply information of potential problems that could lead to a hazardous state of the system, including from the battery management systems (BMS) or the energy storage management system (ESMS). The EWCS shall use compatible communication interface methods with its various sources of information from the ESS.	Complied.	P
18.2.3	The EWCS shall communicate with an operator station that is monitoring the ESS. The EWCS shall be capable of sending information to an external operating station. The EWCS shall also communicate to a local warning system that utilizes audio and visual warning signals when the ESS is operating in a hazardous state. Those conditions that require immediate intervention and notification of the fire service shall result in operation of an external warning signal such as a warning light and audio alarm. NOTE: The methods of communication to the external operating station can vary depending upon the design of the system.	Complied.	P

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Clause	Requirement + Test	Result - Remark	Verdict
18.2.4	The EWCS and the sources providing information to the EWCS shall be evaluated as part of the safety analysis of the system in Section 15. The analysis shall identify those signals/information from the various sources that would warrant the EWCS to provide warning communications to operators and local alarms that the system may have a potential safety issue that needs to be addressed to prevent further escalation. Those signals that signify the need for an escalation of the warning to the local fire department shall also be identified in the analysis. The analysis shall determine that the EWCS is capable of receiving the signals from the various sources to send communication to the operators as necessary. NOTE: Examples of information that may be fed into the EWCS from the BMS or EMS are overvoltage conditions, over temperature conditions, excessive BMS error messages, operation of overcurrent devices, integral gas detection indicating cell venting, etc	Complied.	P
18.2.5	The EWCS shall be installed as an integral component of the ESS. It can be supplied by the lithium batteries it is monitoring, but the EWCS shall also have a dedicated backup power source independent of the batteries it is monitoring to prevent data to and from the EWCS being lost or interrupted as part of the primary power source failure, or delayed by more than 10 s. The backup power source shall be capable of providing power for at least 5 h for the data input and operator communication portion of the system. This back power source need not supply any visual or audible sirens supplied as a part of the system for more than 5 min.	Complied.	P
18.2.6	Instructions on the installation, operation and any ongoing maintenance of the EWCS including its back up power source shall be provided with the ESS instructions. If installed indoors, the instructions shall reference applicable criteria from the Notification Appliances Chapter of NFPA 72, for location and required intensity of visual and audio alarms to be installed in the installation. Visual alarms shall be in accordance with UL 1638, and audio alarms shall be in accordance with UL 464/ULC 525. The maximum sound level for audio alarms shall not exceed 110 dBA at the minimum hearing distance. For outdoor installations, visible alarms installed on the ESS, shall be located no less than 203.2 cm (80 in) nor more than 243.8 cm (96 in) above the ground.	Complied.	P
19	Heating and Cooling Systems		P

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Clause	Requirement + Test	Result - Remark	Verdict
19.1	Energy storage systems that rely upon thermal management systems, either integral to the system or provided at the installation site, to prevent overheating or operation outside the specified safe operating range of the energy storage technology shall be designed to safely shutdown upon failure of the thermal management system unless it can be demonstrated, that the thermal management system failure does not result in a hazardous situation.	HVACs were used for maintaining normal ambient internal temperature of DC ESS. Chiller in each M-LINK is purposed to cool down the heat generation from normal operation of rechargeable Li-ion battery systems.	P
20	Piping Systems, Pressure Vessels, Fuel and Other Fluid Supply Connections and Controls		P
20.1	Piping systems, pressure vessels, fuel and other fluid supply connections and controls shall comply with 20.2 – 20.10. Exception No. 1: Systems that are evaluated as part of a battery to UL 1973 need not comply with 20.2 – 20.10. Exception No. 2: Coolant systems can be evaluated to the performance requirements of the Specific Requirements for Liquid Cooled PDS clause in UL 61800-5-1 or CSA C22.2 No. 61800-5-1.	Coolant flowing piping systems connected between chiller and rechargeable Li-ion battery systems were polymetric materials and complied to relevant requirement of pressure and parts in contact with electrolyte (other than elastomeric materials) in ANSI/UL1973.	P
20.2	Piping systems utilized to carry fluids in an ESS such as water, heated air, fuel gases, etc. shall comply with ASME B31 (all applicable parts), or CSA B51, or CSA B52, or CSA Z662, or CSA B149.1 as applicable.	See above.	N/A
20.3	Pressure vessels and related equipment including pressure relief devices that fall under the scope of ASME BPVC, or CSA B51, shall comply with the applicable requirements.	No pressure vessels in DC ESS.	N/A
20.4	Flammable fuel supply connections on the ESS shall be suitable for the material contained and in accordance with the applicable part of ASME B31 based upon the fluid, temperatures and pressures they are subjected to.	No flammable fuel supply exists	N/A
20.5	A means shall be provided to prevent backflow of process gases, etc. into the fuel supply lines either as part of the ESS design or indicated in the installation instructions.	See above.	N/A
20.6	The ESS shall be designed so that process water used in the system shall be prevented from contaminating potable water sources in accordance with local regulations through the use of check valves or other means as part of the system design.	No water is used in the system.	N/A
20.7	Piping, hose, and tubing containing fluids, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard (e.g. liquid leaking onto electrical circuits that can lead to short circuits). Pressure relief valves shall be located so that fluids are not directed toward live parts or safety critical circuits should they operate.	Complied. No pressure relief valves exists but chiller controls the pressure of coolant flowing.	P

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Clause	Requirement + Test	Result - Remark	Verdict
20.8	ESS containing liquids, including ESS with coolant systems containing liquid coolant, shall be provided with some means of leak detection to monitor for loss of coolant that could lead to a potential hazardous condition. Coolant leaks that are detected shall result in a warning signal to the ESS monitoring and control system and shall initiate an alarm if provided.	Complied. Leak detection functionality was evaluated by functional safety and hazardous condition and failure mode analysis were conducted.	P
20.9	Manual shut off valves shall be provided on or near the ESS in a location where they can be accessed to allow for disconnection of the fuel or water supply to the ESS for maintenance, etc. If not provided on the system itself, installation instructions shall indicate type, ratings and location for installation of appropriate manual shut off valves. Automatic (nonelectric type) and manual valves intended for the use in flammable fluid lines shall comply with UL/ULC 842. Solenoid valves shall comply with UL 429 or CSA C22.2 No. 139. Where flammable liquids are in use, an automatic shutoff valve shall be provided to limit the release of fuel during an abnormal condition.	Chiller operation shall be considered.	N/A
20.10	Pressure regulators used on flammable or other hazardous gas lines shall comply with UL 252, CSA Z662, or CSA B149.1, as applicable.		N/A
21	Containment of Moving Parts in Mechanical ESS		N/A
21.1	Mechanical ESS having moving parts with the capacity to store kinetic energy (flywheel systems) shall be provided with a means to contain the moving parts in the event they could become loosened during operation or through the influence of external forces. If it is possible for moving parts to become dislodged upon breakage or damage to their securement means, the containment mechanism shall adequately contain the loosened moving parts to prevent hazards to persons or the surrounding built environment. See Section 37.	Electrochemical ESS Product.	N/A
21.2	The alternator/generator elements associated with mechanical ESS shall comply with UL 1004-1 and other parts (UL 1004-2, UL 1004-3, UL 1004-5, UL 1004-6, UL 1004-7, UL 1007-8, UL 1004-9) as applicable or CSA 22.2 No. 100.	Electrochemical ESS Product.	N/A
22	Noise Levels		P

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Clause	Requirement + Test	Result - Remark	Verdict
22.1	The noise level from an ESS during operation, including noise levels in walk-in ESS that can be entered during operation, shall be limited to an 8-hr time-weighted average of 85 dBA when tested in accordance with 29 CFR 1910.95 (C)(1)(2). Measurements of the sound are determined in accordance with 29 CFR 1910.95 or equivalent method. Systems that have noise levels in excess of this limit shall be provided with warning labels and instructions that address hearing protection and other protective measures to be taken for those who may be exposed to the noise in accordance with 29 CFR 1910.95. NOTE: 29 CFR 1910.95 (C) (1)(2) indicates an 8-hr limit of 90 dBA, unless exposures can exceed 85 dBA greater than 50 % of the time. The lower 85 dBA is chosen as this is a limit in accordance with NIOSH limits and other standards. This still exceeds the limits of the EU machinery directive, which is 80 dBA.	Non walk-in ESS. The external noise of product was declared < 85 dBA.	P
23	Hazardous Fluid Control		N/A
23.1	Where the system contains fluid in excess of 208 L (55 gal) in a single vessel or an aggregate of more than 3785 L (1000 gal), secondary containment shall be provided. Methods utilized for spill control shall be sufficient to contain all of the fluid from the largest liquid vessel within the system and designed to prevent inadvertent filling with rain if located outdoors. Where flammable liquids are contained, any applicable fire detection and protection systems shall be specified or included as determined per Section 26. The spill control system shall accommodate additional water from any specified fire protection system for a period of 10 min. Automatic leak detection to annunciate the spillage of fluid shall be provided. *Exception: If containment is not provided as part of the product, then instructions regarding the need to provide containment, fire detection and protection systems and leak detection shall be included in the instruction manual. The instructions shall also specify the minimum volume of the containment and information about compatibility of the containment system with the fluid to be contained. See 46.12.*	No hazardous fluid exists.	N/A
23.2	Where a system contains conductive fluids, the system shall be designed in a manner to prevent the fluids from causing a short circuit in the event of a spill. If spill control is not provided with the system, then the instruction manual shall provide directions on the spill control system design to prevent any short circuits from fluid spilled.	No hazardous fluid exists.	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
23.3	Neutralization of spills of any hazardous fluids shall be provided if necessary to insure compatibility with any materials the fluids may contact when in the spill control system. Such neutralization shall occur without the intervention of people and shall have the capacity to neutralize the volume of fluid specified in 23.1 to a pH level that is compatible with the materials in the spill control system. If required, neutralization shall be provided to insure safe clean up and disposal of the spill. *Exception: If neutralization is not provided as part of the product, then instructions regarding the need to provide neutralization shall be included in the instruction manual. The instructions shall also specify the type and quantity of neutralizing material required to meet the requirements of 23.3. See 46.12.*	No hazardous fluid exists.	N/A
23.4	Energy storage systems that contain fluids shall be designed to prevent venting of toxic vapors in concentrations considered to be hazardous based on an evaluation conducted in accordance with Sections 38 and 39.	No hazardous fluid exists.	N/A
24	Combustible Vapor Concentrations		P
24.1	Enclosures of ESS that contain flammable fluid systems or batteries that vent hydrogen or other flammable gases to the atmosphere under normal operations shall be ventilated to prevent hazardous vapor concentrations unless electrical equipment located within the classified area/zone within the enclosure is rated for a Class I Division 1 classification or Zone 1 area/zone. Concentrations in non-hazardous areas/zones of the ESS shall be limited to 25 % of the lower flammability limit (LFL) under normal maximum operating conditions. Mechanical ventilation relied upon to maintain concentrations below the required limits shall be interlocked, so that the system shuts down upon failure of the ventilation system. *Exception: Vented battery systems with aqueous electrolytes such as lead acid or nickel cadmium that are provided with ventilation openings in their enclosures in accordance with 24.3, need not comply.*	No flammable fluid system exists.	N/A
24.2	Electrochemical ESS which are not addressed in 24.1 and which are dependent on mechanical ventilation as a protection measure against emission of flammable gas that can occur during fault conditions to prevent hazardous gas concentrations within the system, shall be equipped with a fault detection system that activates the mechanical ventilation in a manner which prevents the LFL from exceeding 25 % in any non-hazardous area/zone within the ESS.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
24.3	For ESS that contain batteries or similar storage devices, openings to prevent hazardous concentrations of flammable gases within an enclosure can be used. Openings in the enclosure provided for ventilation shall be constructed to prevent accumulation of flammable gases that could lead to a hazardous condition from concentrations of hydrogen gas due to electrolysis of aqueous electrolytes for applicable battery technologies, such as vented or valve regulated lead acid and nickel batteries and applicable electrochemical capacitor technologies, greater than 25 % of the LFL of hydrogen (equivalent to 1 % concentration in a volume of air).	Active ventilation system exists and operated by combustible gas detector and smoke detector. The product DC ESS consists of Rechargeable Li-ion Battery Racks. Li-ion batteries do not generate gas during normal operation, therefore exhaust ventilation is not required in the standard and NFPA 855 code. However, it is for the purpose of preventing explosions after cell venting and thermal runaway in abnormal situations.	N/A
24.4	As an alternative to 24.3, ventilation openings shall have a minimum opening area of: A = 0.005NC5(cm3) Where: *A* = Total cross sectional net free area of ventilation openings required (cm2) *N* = Number of cells in battery *C*5 = Capacity of battery at the 5-h rate (Ah) *Exception: The area of ventilation openings can be reduced if it can be demonstrated that there is sufficient ventilation within the battery to prevent hydrogen accumulations above 25 % of the LFL of hydrogen.*	The product DC ESS does not generate gas during normal operation,	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
24.5	Electrochemical ESS with integral enclosures where there is the potential for a flammable gas concentration within the enclosure from an abnormal condition such as thermal runaway and propagation, shall be provided with deflagration or explosion protection in accordance with NFPA 68 or NFPA 69. This protection shall be installed on the ESS or its enclosure depending upon the type of protection and installed in a location where its operation shall not result in the introduction of a hazard after installation. See the figure for BESS Deflagration Protection Analysis, in the Annex for Test Concepts and Application of Test Results to Installations in UL 9540A for reference and guidance. *Exception No. 1: The protection is not required if the testing in accordance with UL 9540A with a deflagration hazard analysis demonstrates that the concentration of flammable gas measured during testing remains under 25 % LFL within the room, building, ESS cabinet, or walk-in ESS and there is no potential for partial volume deflagration.* *Exception No. 2: For ESS cabinets/enclosures, protection other than as noted can be used if it has been determined that the ESS cabinet/enclosure has been designed to effectively protect against hazards due to combustible concentrations when the ESS has been tested in accordance with the Unit Level or Installation Level test of UL 9540A.*	The product DC ESS consists of Rechargeable Li-ion Battery Rack. Active ventilation system exists and operated by combustible gas detector and smoke detector. Deflagration panel is implemented on M-LINK model LINK-S-MLK-F only.	P
24.6	Portions of ESS, in which flammable vapor concentrations above 25 % LFL may be present during normal operating conditions, shall be provided with construction suitable for the classification in accordance with NFPA 70, CSA C22.1, or IEEE C2 as applicable to the intended installation.	The product DC ESS does not generate gas during normal operation,	N/A
24.7	Electrical compartments adjacent to classified zones within the ESS enclosure shall be maintained at positive pressure in accordance with NFPA 497, UL 60079-2 or CSA C22.2 No. 60079-2.		N/A
25	Flammable Solids		N/A
25.1	ESS containing hazardous solids (i.e. pyrophoric or water reactive metals) shall be designed and installed in accordance with NFPA 484.	No hazardous solids exist	N/A
26	Fire Detection, Suppression and Propagation		P
26.1	General	FACP is installed along with smoke detector(s), combustible gas detector, and active ventilation system. Refer to the fire safety logic in the system.	P

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Clause	Requirement + Test	Result - Remark	Verdict
26.1.1	Fire detection and fire suppression equipment provided as an integral part of an ESS shall comply with applicable product safety standards and shall be installed in accordance with the applicable safety product standards and the manufacturer's instructions.	See above.	P
26.1.2	Energy storage systems with integral fire detection or fire suppression systems shall be provided with instructions for installing, commissioning, maintaining and testing these systems in accordance with applicable installation codes and standards. NFPA 1 and ICC IFC provide information on applicable requirements and codes for fire suppression systems. See also Annex A.	See above.	P
26.1.3	If the ESS manufacturer's instructions indicate that an integral fire detection or fire suppression system is optional, the ESS shall comply with all applicable performance requirements in this Standard with and without the integral fire detection or fire suppression system in place and operational.	See above.	P
26.2	Large scale fire testing		P
26.2.1	Electrochemical type ESS, including but not limited to capacitor and battery ESS, shall be subjected to the large scale fire testing in accordance with UL 9540A as follows in (a) – (d). a) Systems with increased energy capacities as required in codes and standards; b) Systems with decreased separation distances to adjacent ESS units, doors and windows, or exposures. See 46.2 and/or 46.4; c) Indoor systems; or d) Systems for installation in dwelling units (where permitted). NOTE: See Annex E for guidance on code limits related to separation distances and energy capacity.	Complied. Refer to UL9540A battery cell, module, and unit level test reports.	P
26.2.2	Electrochemical ESS intended for use in the living or habitable space of a residential dwelling unit (where permitted) shall meet the Performance – Cell Level Test requirements in UL 9540A. Systems complying with these requirements shall be marked in accordance with 45.3(e)(1). NOTE: CSA C22.1 indicates the following wording for this marking "This equipment meets the cell level performance criteria of UL 9540A". See 45.3(e)(2).	Commercial and Industrial Application.	N/A
26.2.3	Electrochemical ESS intended for use in dwelling units where UL 9540A testing is indicated per the codes and standards, shall minimally meet the Unit Level Performance Criteria for residential installations identified in UL 9540A with a test that aligns with the manufacturer's installation instructions. These ESS shall be marked in accordance with 45.3(e)(3).	Commercial and Industrial Application.	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
26.2.4	Electrochemical ESS intended for non-residential use shall be subjected to specific large scale fire testing in accordance with UL 9540A for installations described in the manufacturer's instructions.	Complied. Refer to UL9540A battery cell, module, and unit level test reports.	P
27	Power Conversion Equipment		N/A
27.1	General	DC Energy Storage System Subassemblies.	N/A
27.1.1	Inverters, chargers, and charging charge control equipment that are part of an energy storage system shall be designed and rated for use with the battery system employed in the energy storage system and evaluated to UL 1741, UL 62109-1 or CSA C22.2 No. 62109-1, UL 1012, UL 62368-1/CSA C22.2 No. 62368-1, or CSA C22.2 No. 107.1 as applicable to the power conversion equipment and its application in the system. *Exception: UL 1778/CSA C22.2 No. 107.3 may be used as an alternative to the power conversion and charger equipment standard references if applicable to the ESS application serving an uninterruptible power system (UPS).*	See above.	N/A
27.2	Utility grid interaction	DC Energy Storage System Subassemblies.	N/A
27.2.1	Energy storage systems intended to export energy to the electric power systems (EPS)/electric utility shall be designated as utility-interactive, grid support utility-interactive, or special purpose utility-interactive and shall utilize the appropriately evaluated power conditioning systems. See 6.41, 6.44, and 6.45.	See above.	N/A
27.2.2	The inverter shall be designed to properly interconnect with the particular energy storage technology it is connected to as determined by the system safety analysis.	See above.	N/A
27.2.3	Products that rely upon internal or external utility interconnection protection functions or devices shall be specifically identified for the particular product in the ESS instructions.	See above.	N/A
27.3	Utility grid interactive inverter	DC Energy Storage System Subassemblies.	N/A
27.3.1	A utility-interactive inverter, grid support utility-interactive inverters, or subassembly of an ESS shall comply with UL 1741, UL 62109-1 or CSA C22.2 No. 62109-1, or CSA C22.2 No. 107.1.	See above.	N/A
27.3.2	Utility-interactive ESS inverters shall be evaluated for compliance with additional utility interactive document(s) and standard(s) if those specific documents or requirements are referenced in the product ratings or instructions.	See above.	N/A
27.4	Standalone and multi-mode power conditioning systems	DC Energy Storage System Subassemblies.	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
27.4.1	Power conditioning systems for standalone and multi-mode applications shall comply with UL 1741, UL 62109-1 or CSA C22.2 No. 62109-1, or CSA C22.2 No. 107.1.	See above.	N/A
28	Energy Storage System Technologies		P
28.1	Electrochemical ESS	Rechargeable Li-ion Battery System.	P
28.1.1	Batteries, electrochemical capacitors, hybrid battery-capacitor systems or flow batteries used in an electrochemical ESS shall comply with the requirements of UL 1973. Testing and evaluation of the battery system, which would include the battery and its battery management system is conducted as part of evaluation to UL 1973. Inverters and charging equipment that are part of the ESS shall be designed for use with the battery system employed in the ESS. For general information on battery safety, see also informative Annex B. *Exception: For valve regulated or vented lead acid or nickel cadmium battery systems, see Annex D for an alternative approach.*	See above.	P
28.2	Chemical ESS		N/A
28.2.1	A chemical ESS consists of storage of hydrogen fuel and the means to change the fuel into electrical energy using a fuel cell system or a hydrogen gas turbine. To convert electrical energy into hydrogen fuel, a hydrogen generator using water electrolysis is also part of the overall system. Fuel cell systems that are part of a chemical ESS shall comply with CSA FC 1, Fuel Cell Power Systems.		N/A
28.2.2	Stationary engine generators that are part of a chemical ESS shall comply with UL 2200 or CSA C22.2 No. 100, and CSA C22.2 No. 286.		N/A
28.2.3	Water electrolysis type hydrogen generators used in an ESS to provide hydrogen for storage shall be evaluated and found to be in compliance to an appropriate safety standard for the equipment.		N/A
28.2.4	Hydrogen fuel containing parts of a chemical ESS shall be constructed of materials suitable for gaseous hydrogen service at the pressures and temperatures of use. Pressure vessels used for storage of gaseous hydrogen and piping employed as part of a chemical ESS shall comply with Section 20.		N/A
28.3	Mechanical ESS		N/A
28.3.1	Mechanical ESS such as, but not limited to, flywheel systems or compressed air energy storage (CAES) systems shall be evaluated to determine that hazards associated with moving parts with the capacity to store kinetic energy, and high pressure and high temperature fluids contained in the system are mitigated. Compliance is determined by evaluation to the requirements of this Standard.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
28.3.2	Flywheel systems and other systems with moving parts with the capacity to store kinetic energy shall comply with the Containment of Moving Parts tests of Section 37 and the Strength Tests of Section 39. Parts containing hazardous fluids shall comply with the Leakage Tests of Section 38 and the Strength Tests of Section 39.		N/A
28.3.3	Flywheel energy storage devices with a maximum surface speed of 200 m/s or less fall within standard electric generator design practice and shall be evaluated in accordance with the Standard for Electric Generators, UL 1004-4 or the Standard for Motors and Generators, CSA 22.2, No. 100. *Exception: In some cases, flywheel energy storage systems with maximum surface speeds of 200 m/s or less may have features such as magnetic bearings that are not commonly found on ordinary electric machines as covered in UL 1004-4 or CSA 22.2, No. 100. The safety of these features shall be evaluated and tested to all applicable requirements in this Standard.*		N/A
28.4	Thermal ESS		N/A
28.4.1	A thermal ESS consists of gases, fluids, and/or solids storing heat energy that can be turned into electrical energy when needed through the use of energy conversion equipment (e.g. engines, generators). NOTE: The three types of thermal ESS are sensible heat, latent heat and thermochemical thermal ESS.		N/A
28.4.2	Thermal ESS shall be evaluated to determine hazards associated with containment of high temperature and high pressure and potentially hazardous fluids are mitigated. Compliance is determined by evaluation to the requirements of this Standard. Parts containing hazardous fluids and fluids at high temperatures and pressures shall comply with the Leakage Tests of Section 38 and the Strength Tests of Section 39.		N/A
28.4.3	Stationary engine generators that are part of a thermal ESS shall comply with UL 2200 or CSA C22.2 No. 100, and CSA C22.2 No. 286. Generators that are part of a thermal ESS shall comply with UL 1004-4 or CSA C22.2 No. 100.		N/A
28.4.4	Hazardous fluid containing parts of a thermal ESS shall be constructed of materials suitable for use with that fluid at the pressures and temperatures of use. Pressure vessels used for storage and piping employed as part of a thermal ESS shall comply with Section 20. Stresses on containment parts associated with swings of high and low temperature extremes shall be considered when evaluating the suitability.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
28.4.5	Containment systems for combustible materials (solids or fluids) shall be designed to prevent the potential for explosion hazards as a result of contact with moisture, contaminants, etc.		N/A
28.4.6	A thermal ESS shall have sufficient pressure controls, fluid level controls and temperature controls to prevent the potential for a hazardous condition from occurring through an out of specification operation. Compliance is determined through the safety analysis of the system and the functional safety investigation of the controls per Section 15 and the abnormal operations tests for thermal ESS in accordance with Section 31.		N/A
	PERFORMANCE		P
29	General	Complied.	P
29.1	The energy storage technologies employed as part of an ESS shall be tested and determined compliant to an applicable technology safety standard. Where no applicable safety standard exists, they shall be tested in accordance with this Standard.	Li-ion technology was used. Applied ANSI/UL1973 as the safety standard.	P
29.2	All tests conducted in accordance with this Standard shall be conducted in an environment with a room ambient temperature of 25 ±5 °C (77 ±9 °F), unless otherwise noted in the test method. Any cooling systems or other auxiliary systems that are part of the ESS shall be operating during testing when their operation can affect the outcome of the test or when otherwise noted in the test method. For testing purposes, samples and parameters used for testing shall consider smallest size conductors and maximum allowed overcurrent protection in addition to worse case loading and temperatures conditions.	Used HVAC(s) for controlling internal ambient temperature of subassembly parts of E-PANEL and M-LINK, The enclosure of DC ESS is for outdoor use.	P
29.3	Temperature shall be measured using thermocouples consisting of wires not larger than 0.21 mm2 (24 AWG) and not smaller than 0.05 mm2 (30 AWG) connected to a potentiometer-type instrument. Temperature measurements shall be made with the measuring junction of the thermocouple held tightly against the component/location being measured. For those tests that require the sample to reach thermal equilibrium (also referred to as steady state conditions), thermal equilibrium is considered to be achieved if after three consecutive temperature measurements taken at intervals of 10 % of the previously elapsed duration of the test but not less than 15 min, indicate no change in temperature greater than ±2 °C (±3.6 °F).	Complied.	P

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Clause	Requirement + Test	Result - Remark	Verdict
29.4	The tests contained in this Standard may result in explosions, fire and emissions of flammable and/or toxic fumes as well as electric shock. It is important that personnel use extreme caution and follow local and regional worker safety regulations when conducting any of these tests and that they be protected from flying fragments, explosive force, and sudden release of heat and noise that could result from testing. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases. As an additional precaution, the temperatures on surfaces of parts that may get hot or cold during testing may be monitored during the test for safety and information purposes. All personnel involved in the testing shall be instructed to never approach the device under test (DUT) until temperatures have returned to within room ambient temperatures.	Complied.	P
	ELECTRICAL TESTS		
30	Normal Operations Test		P
30.1	A normal operations test can be waived for equipment of an ESS where a similar evaluation such as a temperature test has already been conducted under the specific technology standard.	A representative DC ESS was subjected for the normal operations test.	N/A
30.2	In conducting the electrical tests required in this Standard, the ESS shall be operated through a minimum of 2 cycles of charge and discharge of the system at the maximum loading rates as specified by the manufacturer. If a duty cycle is specified as noted in 45.4, then the discharge and charge cycles shall be repeated at the specified duty cycle until maximum temperatures during each part of the cycle achieve equilibrium. For each cycle, the ESS shall be discharged completely, recharged immediately to a full state of charge, followed by a delay to achieve the specified duty cycle. *Exception: Normal operations testing on a subassembly may be conducted instead of the complete ESS if through analysis it can be determined to be representative of the ESS. The rationale used to determine the suitability of the subassembly to represent the complete ESS shall be documented.*	Total two(2) cycles of charging and discharging were applied. Maximum charging and discharging profile of 0.25CP rating was used.	P
30.3	During the test, consideration shall be given to maximum and minimum room ambient conditions. During operation, temperatures on critical components that are temperature sensitive shall be monitored and operating parameters of components of the system monitored to determine that they are operating within their ratings. If the ESS is intended for mounting on a wall, it shall be mounted as intended in accordance with installation instructions on a flat wall in an alcove that is painted a dull black, and temperatures shall be monitored on the wall surfaces during the test.	The product is outdoor use. The operation of HVAC and Chiller maintain the temperature environmental condition of power flowing subassemblies. e.g.) rechargeable Li-ion battery systems, etc.	P

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Clause	Requirement + Test	Result - Remark	Verdict
30.4	During the normal operations test, the manufacturer's specified limits shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications in accordance with Table 30.1. Temperatures on accessible surfaces of the ESS shall not exceed the limits in accordance with Table 30.2.	No sign of exceeding temperature limit was observed.	P
31	Abnormal Operation Tests for Thermal Energy Storage Systems		N/A
31.1	General	Electrochemical ESS	N/A
31.1.1	Thermal ESS shall remain in a safe state should the thermal controls, fluid controls or pressure controls of the system fail.	See above.	N/A
31.2	Failure of thermal controls	See above.	N/A
31.2.1	The thermal ESS shall be operated during charging and discharging with a single fault within the thermal control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.	See above.	N/A
31.2.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the test, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.	See above.	N/A
31.3	Exposure to out of specification thermal conditions	See above.	N/A
31.3.1	The thermal ESS shall be subjected to a temperature conditions outside of the operating specifications of the system to determine if the controls will prevent an over temperature condition or other condition that could lead to a hazard. The ESS or a representative subassembly shall be subjected to an ambient of 70 °C (158 °F) or 20 °C (36 °F) above the maximum specified operating ambient, whichever is higher and then an ambient of -30 °C (-22 °F) or 20 °C (36 °F) below the lowest specified operating ambient, whichever is lower. The ESS shall be operated during this conditioning. For example, if supplied by solar, so that charging takes place during the day, the high temperature exposure shall take place during the charging phase. If the discharging phase is in the evening, the cold temperature exposure shall take place during the discharge phase. Only one complete cycle of charge and discharge is required, and the DUT shall be charged or discharged until the end of each condition or until thermal controls stop the operation.	See above.	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
31.3.2	As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids. Thermal controls shall prevent the system from operating outside of safe limits.	See above.	N/A
31.4	Failure of pressure controls	See above.	N/A
31.4.1	The thermal ESS shall be operated during charging and discharging with a single fault within the pressure control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.	See above.	N/A
31.4.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.	See above.	N/A
31.5	Failure of fluid controls	See above.	N/A
31.5.1	The thermal ESS shall be operated during charging and discharging with a single fault within the various fluid level control systems relied upon for safety. Examples of these systems can include a gas system used to provide an inert atmosphere within containment chambers, a liquid leak control, etc. The test shall be repeated with the single fault in each separate fluid level control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.	See above.	N/A
31.5.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.	See above.	N/A
32	Dielectric Voltage Withstand Test	Complied.	P
32.1	The dielectric voltage withstand test is an evaluation of the electrical spacings and insulation associated with the hazardous voltage circuits within the DUT.	Electrical insulation between primary and secondary circuits were subjected to be tested. Live parts and dead metals were selected as the additional insulation and spacing check.	P

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Clause	Requirement + Test	Result - Remark	Verdict
32.2	Circuits at 42.4 Vpeak/ 30 Vrms or 60 Vdc or higher shall be subjected to a dielectric withstand voltage in accordance with the “Determining clearances using required withstand voltage” clause of UL 62368-1/CSA C22.2 No. 62368-1. *Exception No. 1: Semiconductors or similar electronic components liable to be damaged by application of the test voltage shall be bypassed or disconnected.* *Exception No. 2: The dielectric voltage withstand test need not be conducted on integral ESS, fuel cells, and inverter systems, etc. that have already been evaluated in accordance with their individual standard requirements. Only those electrical parts external to the tested systems and their connections not previously evaluated need to be tested.*	Complied.	P
32.3	The voltage applied during the dielectric voltage withstand test is to be applied between the hazardous voltage circuits of the DUT and accessible non-current carrying conductive parts.	Complied.	P
32.4	The voltage applied during the dielectric voltage withstand test is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the DUT.	Complied.	P
32.5	The voltages applied during the dielectric voltage withstand test shall be applied for a minimum of 1 min.	Min. 1 minute.	P
32.6	The test equipment shall consist of a 500 VA or larger capacity transformer, the output voltage, which is variable and which is essentially sinusoidal if using ac test method, a dc output if using a dc test method. There is no trip current setting for the test equipment since the test is checking for insulation breakdown, which results in a large increase of current. Setting a trip current may result in a false failure of this test, as it is not necessarily indicative of insulation breakdown. *Exception: A 500 VA or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.*	Complied.	P
32.7	There shall be no evidence of a dielectric breakdown (breakdown of insulation resulting in a short through insulation/arcing over electrical spacings) as evidenced by an appropriate signal from the dielectric withstand test equipment as a result of the applied test voltage. Corona discharge or a single momentary discharge is not regarded as dielectric breakdown (i.e. insulation breakdown).	No sign of breakage	P
33	Impulse Test	Complied.	P

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Clause	Requirement + Test	Result - Remark	Verdict
33.1	The impulse voltage test is intended to evaluate the ESS's ability to withstand lightning or similar surges. Systems provided with protection that has already been evaluated for voltage surges (e.g. inverters meeting IEEE 1547 criteria) need not be tested if it can be determined that the parts connected to the power conditioning system can withstand any let through current that may occur.	Complied. Used Recognized Components of Surge Protection Device(SPD) were considered for testing.	P
33.2	The impulse voltage test shall be performed with an impulse generator able to provide voltage having a 1.2/50 µs waveform (see the Full Impulse Voltage Time Parameters figure of IEC 61180) at voltages in accordance with Table 33.1, and is intended to simulate an overvoltage condition due to lightning or switching of equipment.	Complied.	P
33.3	Pulses shall be applied at 1.2/50 µs for each polarity in ≥ 1 s time intervals at the peak voltage for the rating of the circuit under test ±5 % per Table 33.1. The test voltage is to be applied between the terminal/circuit under test and accessible parts. For circuits at 1000 V or less, three pulses at each polarity shall be applied. For circuits over 1000 V, 5 pulses at each polarity shall be applied. Exception: Impulse test levels can be based on the transient voltage surge suppression device rating if provided.	More severe condition of 5 pulses was applied regardless circuit voltage from I/O terminals.	P
33.4	As a result of the applied impulse voltage test, there shall be no puncture of insulation (i.e. electrical breakdown through solid insulation), occurrence of flashover (i.e. electrical breakdown over the surfaces of solid insulation), or spark-over (i.e. electrical breakdown through fluids such as air).	Complied. Sample remained intact.	P
34	Equipment Grounding and Bonding Test	Complied.	P
34.1	The impedance of the system grounding and bonding circuit shall be determined using one of the following methods: a) The circuit between the grounding terminal and the part to be grounded is measured using impedance measuring equipment; b) In accordance with the Continuity of the Equipment Grounding Circuit section, Section 18.2 of NFPA 79 (voltage drop measurement of the circuit using a 10 A low voltage supply source); or c) In accordance with test in the "Resistance of the Protective Bonding System" clause, Clause 5.6.6 of UL 62368-1/CSA C22.2 No. 62368-1 (measuring voltage drop in circuit using a low voltage supply source providing a current based upon circuit protection rating). d) The fault loop impedance measurement in accordance with IEC 60364-4-41. In Canada, the circuit under test is referred to as the bonding circuit per CSA C22.1.	Complied with method a) and b) No Canadian deviation was considered.	P

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Clause	Requirement + Test	Result - Remark	Verdict
34.2	The impedance for all grounding and bonding circuits tested shall not exceed 0.1 Ω, or if using the test method in 30.1(d), the compliance criteria shall be in accordance with IEC 60364-4-41.	Did not exceed 0.1 Ω	P
35	Insulation Resistance Test	Complied.	P
35.1	The resistance of insulation used on hazardous voltage circuits within an ESS shall be greater than or equal to 1 MΩ.	Measured greater than 1MΩ	P
35.2	The insulation resistance shall be measured using high impedance measuring equipment (e.g. mega ohmmeter) while applying a voltage of 500 Vdc between the live parts of the circuit under test and accessible conducting parts including the equipment grounding circuit, for 1 min. *Exception No. 1: Energy storage systems need not be tested if the insulation resistance has been previously evaluated as part of the particular technology safety standard.* *Exception No. 2: The insulation resistance test of IEC 60364-6 can be conducted instead.* *Exception No. 3: This test can be waived if the permanently connected wiring has:* *a) A cross-section of the protective earthing conductor of at least 10 mm2 if copper, or 16 mm2 if aluminum; or* *b) Provision of an additional terminal for a second protective earthing conductor of the same cross-sectional area as the original protective earthing conductor and installation instructions requiring a second protective earthing conductor to be installed.* *Exception No. 4: The touch current measurement test of IEC 62040-1 may be conducted instead.*	A voltage of 1 000 Vdc was used instead of 500 Vdc.	P
35.3	Resistor(s) and/or resistor networks may be removed when conducting the insulation resistance test.	Complied.	P
36	Electromagnetic Immunity Tests		P
36.1	General	Complied.	P

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Clause	Requirement + Test	Result - Remark	Verdict
36.1.1	Electronics and software controls determined to be critical for safety shall demonstrate sufficient immunity to electromagnetic interference by complying with the tests specified in these sections. Alternate test procedures and levels specified in other standards may be used, but only if they are equivalent or more severe than the test procedures and levels specified below. This testing is not required if EMI testing has already been conducted as part of the control's functional safety investigation. *Exception: This testing does not apply to controls within components of the ESS that have already been evaluated for EMI exposure in accordance to their applicable component standard such as UL 1741 for power conditioning systems.*	Safety controls related firmware version and unique identifier were checked before and after electromagnetic immunity tests.	P
36.1.2	Each test shall begin with an operational DUT.		P
36.1.3	During the tests in this section, the DUT shall be operated in mode(s) that include the safety function(s) being evaluated. If multiple modes are to be considered (example: equipment controlling the charging and discharging of the energy storage device), the DUT shall either be cycled through those modes during the tests, or the tests repeated in each mode. While cycling through modes, the DUT shall not exhibit any signs of loss of safety functions or risk of fire, electric shock, or personal injury.	Three modes of charging, discharging and standby were applied.	P
36.1.4	After each test in this section, the DUT shall be inspected to verify that it is still operational. This may require Operational Verification (36.8) of the DUT if it is not possible to determine that it is fully operational by inspection. If the DUT is no longer operational, a failure analysis shall be conducted to determine the reason for the failure and to verify that the DUT has failed safely. A DUT that is no longer operational shall not be used on any remaining test.	DUT remains intact and operational verification was checked.	P
36.1.5	In addition, after all tests in this section have been completed, all samples used during the tests specified in Section 36 shall comply with the Operational Verification in Section 36.8.	Complied.	P
36.2	Electrostatic discharge		P
36.2.1	The DUT shall demonstrate immunity to electrostatic discharges in accordance with the test procedure specified in IEC 61000-4-2 and the modes of operation stated in 36.1.3.	Both contact and air discharge were applied.	P
36.2.2	The following test levels shall be used: a) ±6 kV contact discharge; and b) ±8 kV air discharge.	See above.	P
36.2.3	After the test, the DUT shall comply with 36.1.4.	DUT remains intact and operational verification was checked.	P

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Clause	Requirement + Test	Result - Remark	Verdict
36.3	Radio-frequency electromagnetic field		P
36.3.1	The DUT shall demonstrate immunity to radio-frequency electromagnetic fields in accordance with the test procedure specified in IEC 61000-4-3 and the modes of operation stated in 36.1.3.	Applied all three modes.	P
36.3.2	The following test levels shall be used: a) 10 V/m from 80 MHz to 1 GHz, 1 kHz (80 % AM); and b) 3 V/m from 1.4 GHz to 6.0 GHz, 1 kHz (80 % AM)	Used stated test levels.	P
36.3.3	During the test, the DUT shall comply with 36.1.3.	Complied.	P
36.3.4	After the test, the DUT shall comply with 36.1.4.	Complied.	P
36.4	Fast transient/burst immunity		P
36.4.1	The DUT shall demonstrate immunity to electrical fast transients/bursts in accordance with the test procedure specified in IEC 61000-4-4 and the modes of operation stated in 36.1.3.	Applied all three modes.	P
36.4.2	The following test levels shall be used: a) On signal/control ports intended to be connected to cables longer than 3 m (118.1 in), ±1 kV (5/50 ns, 5 kHz); capacitive clamp shall be used; b) On input and output DC ports, ±1 kV (5/50 ns, 5 kHz); and c) On input and output AC ports, ±2 kV (5/50 ns, 5 kHz).	Used stated test levels.	P
36.4.3	With reference to 36.4.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.4.2(c). External accessible DC ports shall be conducted using the test level specified in 36.4.2(b).	Complied.	P
36.4.4	After the test, the DUT shall comply with 36.1.4.	Complied.	P
36.5	Surge immunity		P
36.5.1	The DUT shall demonstrate immunity to surges in accordance with the test procedure specified in IEC 61000-4-5 and the modes of operation stated in 36.1.3.	Applied all three modes.	P
36.5.2	The following test levels shall be used: a) For I/O signal/control ports intended to be connected to long-distance cables longer than 30 m (1181.1 in), which leave the building, and/or are for outdoor use, ±1 kV line-to-ground; b) For input and output DC ports, ±0.5 kV line-to-line, and ±1 kV line-to-ground; and c) For input and output AC ports, ±1 kV line-to-line, and ±2 kV line-to-ground.	Used stated test levels.	P

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Clause	Requirement + Test	Result - Remark	Verdict
36.5.3	With reference to 36.5.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.5.2(c). External accessible DC ports shall be conducted using the test level specified in 36.5.2(b).	Complied.	P
36.5.4	After the test, the DUT shall comply with 36.1.4.	Complied.	P
36.6	Radio-frequency common mode		P
36.6.1	The DUT shall demonstrate immunity to radio-frequency conducted disturbances in accordance with the test procedure specified in IEC 61000-4-6 and the modes of operation stated in 36.1.3.	Applied all three modes.	P
36.6.2	The following test levels shall be used: a) For I/O signal/control ports intended to be connected to cables longer than 3 m (118.1 in), 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM); b) For input and output DC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM); and c) For input and output AC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM).	Used stated test levels.	P
36.6.3	With reference to 36.6.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.6.2(c). External accessible DC ports shall be conducted using the test level specified in 36.6.2(b).	Complied.	P
36.6.4	During the test, the DUT shall comply with 36.1.3.	Complied.	P
36.6.5	After the test, the DUT shall comply with 36.1.4	Complied.	P
36.7	Power-frequency magnetic field		P
36.7.1	The DUT shall demonstrate immunity to power-frequency magnetic fields in accordance with the test procedure specified in IEC 61000-4-8 and the modes of operation stated in 36.1.3.	Applied all three modes.	P
36.7.2	The following test level shall be used: 10 A/m.	Used stated test levels.	P
36.7.3	During the test, the DUT shall comply with 36.1.3.	Complied.	P
36.7.4	After the test, the DUT shall comply with 36.1.4.	Complied.	P
36.8	**Operational verification**		P
36.8.1	After the tests in 36.2 – 36.7 have been completed, all samples used during these tests shall comply with the following.	Complied.	P
36.8.2	The manufacturer shall declare the anticipated performance of all safety functions performed by electronics and software controls.	Complied.	P

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Clause	Requirement + Test	Result - Remark	Verdict
36.8.3	The manufacturer shall provide test procedures to verify that each of the safety functions performed by electronics and software controls is working correctly. This may include, for example, verification of correct safety function performance by simulation.	Complied. All protective functions under functional safety evaluation were remained intact. Simulated safety function performance were checked after completion normal operation of charging and discharging DUT.	P
36.8.4	During the test procedures specified in 36.8.3, each DUT shall exhibit one of the following behaviors: a) No loss of safety functions; or b) Transition to an appropriate state to ensure safe operation of the DUT.	DUT was fully operational and remained intact after all tests.	P
36.9	**Operational verification of remote software update capability**	No remote software update is available.	N/A
36.9.1	The test of 36.8 shall be conducted on safety controls intended for remote software updates in accordance with Section 16 to ensure that they are operational after the update. See 16.1.7 and 16.2.8.	See above.	P
	MECHANICAL TESTS		P
37	Containment of Moving Parts	No moving part in the product.	N/A
37.1	Control system fault overspeed test	Not applicable.	N/A
37.1.1	An ESS with moving parts having the capacity to store kinetic energy that is capable of being subjected to overspeed conditions through a fault in the system controls shall be subjected to an overspeed test.		N/A
37.1.2	The system controls shall be subjected to single fault in the controls that would allow overspeed of the moving parts. The DUT shall be operated at overspeed conditions until a secondary protection control operates to stop operation of the DUT.		N/A
37.1.3	As a result of the overspeed condition, the moving part(s) shall not become loosened or disconnected in a manner that would result in a hazardous condition. If completely loosened or disconnected as a result of the overspeed conditions, the containment means shall safely contain the part(s) in accordance with the Faulted Securement Test in 37.2.		N/A
37.1.4	The system controls shall limit the overspeed to a level less than the speed defined in 37.4.		N/A
37.2	Faulted securement test	Not applicable.	N/A
37.2.1	An ESS with moving parts with the capacity to store kinetic energy shall be subjected to the faulted securement test when a fault in primary securement means of the moving part has the potential to result in a hazard.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
37.2.2	The moving parts of the system shall be subjected to a single fault of the primary means of securement while operated at the maximum speed anticipated during normal operation. The primary means of securement to be removed, such as a failed bearing, shaft, or other part of the securement of the moving part with respect to the stationary housing, shall be determined through a safety analysis that identifies failure of the selected means as representing the potential worst case condition. Refer to Section 15 for the safety analysis requirements.		N/A
37.2.3	This test is not required in cases where test or field data is available to support the safety analysis indicating that there is not a hazard associated with the loss of primary securement.		N/A
37.2.4	The system shall be operated until one of the following occurs: a) The part has operated for 30 min under the faulted condition; b) A protection control operates to stop operation of the DUT or hazardous moving part; or c) The part has loosened and is completely or partially disconnected from its securement means.		N/A
37.2.5	As a result of the operation with a faulted securement condition, the moving part(s) shall not become loosened or disconnected to result in a hazardous condition. If completely loosened or disconnected, the containment means for the part shall safely contained the part(s).		N/A
37.3	Blocked shaft test	Not applicable.	N/A
37.3.1	An ESS with moving parts with the capacity to store kinetic energy shall be subjected to the blocked shaft test if blocking the shaft or moving parts has the potential to result in a hazard.		N/A
37.3.2	With the moving part blocked to prevent movement, the system shall be operated at the maximum ratings allowed for a zero speed condition.		N/A
37.3.3	The system shall be operated: a) With the part blocked for 30 min and then stopped; b) Until a protection control operates to stop operation of the DUT with the blocked part; or c) Until any moving parts break off or become completely or partially disconnected from its securement means. *Exception: Moving parts already evaluated for blocked shaft conditions as part of a component evaluation, need not be tested.*		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
37.3.4	As a result of operating the system with a blocked shaft/moving part condition, the part shall not become loosened or disconnected to result in a hazardous condition. If the part becomes completely loosed or disconnected, the containment means for the part shall safely contain the part(s). There shall be no overheating of parts that will result in a hazard such as fire or explosion.		N/A
37.4	Mechanical integrity test	Not applicable.	N/A
37.4.1	An ESS with any moving part having the capacity to store kinetic energy shall have the mechanical (i.e. rotating) energy storage elements designed to have a minimum margin factor of safety. The factor of safety requirements vary depending on the material of construction. The factor of safety based on material type shall be as follows: a) For assemblies composed of laminated composite materials, the minimum factor of safety shall be at least 2.0 between the maximum principal stress that exists at the point of highest stress in each layer of the mechanical energy storage element and the ultimate strength of that layer at that point. The factor of safety shall be evaluated at maximum normal operating speed and at a room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F). b) For assemblies composed of ductile metallic materials exhibiting a traditional nonlinear stress-strain curve, the minimum factor of safety shall be at least 1.3 between the maximum von Mises stress that exists anywhere in the mechanical energy storage element at maximum normal operating speed and the tensile yield strength of the material where the stress exists at room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F). c) For other material types and combinations of materials including metals and laminated composites, the minimum factor of safety shall be at least 2.0 between the maximum combined stress that exists anywhere in the mechanical energy storage element at maximum normal operating speed and the ultimate tensile strength of the material where the highest stress exists at room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F).		N/A

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
37.4.2	The mechanical energy storage element shall be subjected to an overspeed type test demonstrating the required factor of safety. The DUT shall be representative of the latest design revision and subjected to an overspeed and corresponding stress as follows in (a) or (b). For the purpose here, rotor working stress is presumed to scale exactly as the square of the rotation speed. a) Where the minimum required factor of safety is 2.0, the overspeed shall be at least 139 %. The DUT shall sustain the overspeed for a time period of 1 min without ruptures in of any part of the assembly. b) Where the minimum required factor of safety is 1.3, the overspeed shall be 120 % minimum. The DUT shall sustain the overspeed for a time period of 1 min. Yielding of the material during the test is permitted as long as the test requirement is met and the DUT can be shut down afterward in a normal manner (i.e. through braking or discharge of the stored energy). This condition implies that margin between the maximum Von Mises stress in the part at normal operating speed and the ultimate tensile strength of the material must be greater than 1.45 to successfully pass the overspeed test.		N/A
37.4.3	With reference to 37.4.2, for a hollow cylindrical mechanical energy storage element, as an alternative to the dynamic test, a static test (e.g. hydrostatic or pneumatic strength test) may be performed whereby the DUT is subjected to an internal pressure that creates maximum stress in the DUT that is greater than 2x the maximum stress under normal operating conditions.		N/A
37.4.4	With reference to 37.4.2 and 37.4.3, the mechanical energy storage element DUT shall: a) Be a production mechanical energy storage element; b) Be according to the latest design revision; and c) Meet the manufacturer's quality assurance requirements for production units.		N/A
37.4.5	Alternatively to the overspeed test requirements of 37.4.2, the standard installation of the energy storage element shall demonstrate containment of a failure of the mechanical energy storage element. Containment is defined as NO primary particles (energy storing components, their fragments, or other moving parts) and NO secondary projectiles (stationary components of the product or their fragments set into motion by the failure event) are to exit the device's outermost housing, containment media, or installation area. This test shall be performed at 100 % of maximum rated operating stress or above.		N/A

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
37.4.6	With reference to 37.4.1 – 37.4.5, the testing shall be repeated in the event of a deviation of any mechanical characteristic or material property that results in an increase of more than 10 % between calculated stress in production energy storage elements and demonstrated stress in the previously qualified mechanical energy storage element.		N/A
37.5	Bearing failure test	Not Applicable.	N/A
37.5.1	An ESS with moving parts with the capacity to store kinetic energy that relies upon a primary set of bearings in its moving mechanism, in any form, shall be subjected to a bearing failure test if failing the bearings has the potential to result in a hazard. Refer to Section 15 for the safety analysis requirements.		N/A
37.5.2	With the system operating at maximum operating conditions, a failure in the primary bearings shall be induced that results in the loss of the primary bearing function and forces the DUT to spin down on its backup bearing or other suitable support system.		N/A
37.5.3	The system shall be operated: a) Until the DUT’s energy is dissipated and it has come to a stop; b) Until a protection control operates to stop operation of the DUT; or c) Until any moving parts break off or become completely or partially disconnected from its securement means.		N/A
37.5.4	This test is intended to verify that the backup bearing or support system for the energy storage element is effective. This test may also suffice as the faulted securement test described in 37.2 if the safety analysis indicates a bearing failure as the worst case condition.		N/A
37.5.5	As a result of operating the system with a failed bearing condition, the moving parts shall not become loosened or disconnected to result in a hazardous condition. If the part becomes completely loosed or disconnected, the containment means for the part shall safely contain the part(s). There shall be no overheating of parts that will result in a hazard such as fire or explosion.		N/A
38	Leakage Tests		P
38.1	Energy storage systems that utilize liquid coolant or contain hazardous fluids shall be subjected to the Leakage Test in accordance with 38.2 and 38.3. *Exception: Leakage testing need not be conducted if parts containing hazardous fluids and their connections have already been evaluated for external leakage as part of a component standard such as the appendix for Test Program for Flowing Electrolyte Batteries, Appendix C, of UL 1973 or CSA FC 1 for fuel cell systems.*	Complied. Liquid coolant flowing path was subjected; however, no hazardous fluid exists.	P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
38.2	Leakage from ESS containing hazardous fluids shall not result in the risk of fire, electric shock, or injury to persons.	See above.	P
38.3	Compliance is determined by subjecting the fluid-containing parts and their connections to a fluid pressure of 1.5 times the maximum operating pressure (if testing with liquid) or 1.1 times the maximum operating pressure (if air pneumatic testing) of intended use during operation of the system. There shall be no leaks from fluid-containing parts or their connections as a result.	Complied. The air pneumatic testing method was used. 1.3 times of operating pressure for 1 minute was applied for more severe condition.	P
39	Strength Tests		N/A
39.1	General		N/A
39.1.1	Energy storage systems that contain hazardous fluids including liquid coolant shall comply with the Strength Tests in accordance with 39.2 and 39.3.	No hazardous fluid exists.	N/A
39.2	Hydrostatic strength test		N/A
39.2.1	Parts of the ESS containing hazardous fluids (gases or liquids) shall be subjected to a hydrostatic strength test of 1.5 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either the liquid used in the system or water. Testing is done at room ambient temperature.		N/A
39.2.2	As a result of the hydrostatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.		N/A
39.3	Pneumatic strength test		N/A
39.3.1	The pneumatic strength test is an alternative to the hydrostatic strength test of 39.2 and is conducted in accordance with 39.3.2.		N/A
39.3.2	Parts of the ESS containing hazardous fluids (gases or liquids) shall be subjected to a pneumatic strength test of 1.3 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either air or inert gas. Testing is conducted at room ambient temperature.		N/A
39.3.3	As a result of the pneumatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.		N/A
40	Enclosure and Mounting Tests		P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
40.1	Wall mount fixture/test	Support structure test on rechargeable Li-ion battery rack frame structure in M-LINK was subjected for testing as per following ANSI/UL1973 Section 34. Wall Mount Fixture/Support Structure/Handle Test	P
40.1.1	A wall mounting apparatus of a wall mounted ESS shall have sufficient strength to support the system. Compliance is determined by the following test. *Exception: Individual components of an ESS that are provided with their own wall mount apparatus previously tested as part of their component evaluation, need not be tested.*	See above.	P
40.1.2	The wall mounting apparatus and ESS shall be installed in accordance with the manufacturer's specifications. A force equal to three times the weight of the ESS is additionally applied to the center of the mounting apparatus in a downward direction. The force shall be held for 1 min.	See above. Total of four times the weight of battery pack was applied on the L brackets of Rack frame was applied.	P
40.1.3	As a result of the applied force, there shall be no damage to the mounting apparatus and its securement means when testing the wall mounting fixture.	Observed intact.	P
40.2	Enclosure impact	Not applicable	N/A
40.2.1	The purpose of this test is to evaluate the mechanical integrity of the enclosure and its ability to provide mechanical protection to the ESS enclosure contents. This test is conducted on electrochemical ESS that are for residential applications or for non-residential applications that are less than or equal to 50 kWh.	Commercial and Industrial application. Greater than 50kWh.	N/A
40.2.2	A fully charged DUT shall be subjected to a minimum of three impacts of 6.8 J (5 ft-lb) on any surface that can be exposed to a blow during intended use. The impact shall be produced by dropping a steel sphere, 50.8 (2 in) in diameter, and weighing 535 g (1.18 lb) from a height, H, of 1.29 m (50.8 in). For surfaces other than the top of an enclosure, the steel sphere shall be suspended by a cord and swung as a pendulum, dropping through the vertical height of 1.29 m (50.8 in), with the product being impacted placed against a restraining vertical wall. See Figure 40.1. A different sample may be used for each impact.	See above.	N/A
40.2.3	After the impacts, the DUT shall be subjected to a Dielectric Voltage Withstand Test in accordance with Section 32. The DUT shall be examined for signs of rupture or damage that could lead to a hazard.	See above.	N/A
40.2.4	As a result of the impact test, there shall be no damage to the enclosure that could result in a hazard such as exposure of hazardous parts or result in a dielectric breakdown.	See above.	N/A

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
40.3	Enclosure steady force	Not applicable	N/A
40.3.1	The purpose of this test is to determine if the enclosure has sufficient strength to safely withstand a static force that may be applied to it. This test is conducted on electrochemical ESS that are for residential applications or for non-residential applications that are less than or equal to 50 kWh.	Commercial and Industrial application. Greater than 50kWh.	N/A
40.3.2	The enclosure of a fully charged DUT shall withstand a steady force of 250 N ±10 N (56.2 lbf ±2.25 lbf) for a period of 5 s, applied in turn to the top, bottom and sides of the enclosure fitted to the DUT, by means of a suitable test tool providing contact over a circular plane surface 30 mm (1.2 in) in diameter.	See above.	N/A
40.3.3	The DUT shall be subjected to a Dielectric Voltage Withstand Test between live parts and the enclosure in accordance with Section 32. The DUT shall be examined for signs of rupture or damage that could lead to a hazard.	See above.	N/A
40.3.4	As a result of the steady force test, there shall be no damage to the enclosure that could result in a hazard such as exposure of hazardous parts or result in a dielectric breakdown.	See above.	N/A
40.4	Mold stress	Not applicable	N/A
40.4.1	The purpose of this test is to determine if an enclosure made from molded polymeric material can withstand an accelerated aging test without compromising the safety of the enclosure.	Metal enclosure	N/A
40.4.2	One complete fully discharged sample shall be placed in a full-draft circulating-air oven maintained at a uniform temperature of at least 10 °C (18 °F) higher than the maximum temperature of the enclosure measured during the Normal Operations Test in Section 30, but not less than 70 °C (158 °F). The sample shall remain in the oven for 7 h.	See above.	N/A
40.4.3	After removal from the oven the DUT shall be subjected to a Dielectric Voltage Withstand Test in accordance with Section 32. The DUT shall be examined for signs of rupture and damage	See above.	N/A
40.4.4	As a result of the mold stress conditioning, the sample shall show no evidence of mechanical damage, such as cracking of the enclosure exposing hazardous parts or result in a dielectric breakdown.	See above.	N/A
	ENVIRONMENTAL TESTS		P
41	Special Environment Installations		P
41.1	General		P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
41.1.1	Energy storage systems intended for installation in special environments shall be evaluated for their ability to operate safely in those environments. These environmental conditions can include exposure to salt fog for marine environments, testing for seismic ratings, high altitudes, etc. The requirements of 41.2, 41.3 and 41.4 shall apply depending upon the particular exposure. The installation instructions and nameplate labels on the ESS shall identify the special environmental conditions in accordance with 45.3, 45.17, and Section 46. *Exception No. 1: Testing need not be conducted on systems or parts of the system if already covered as part of the specific technology safety standard.* *Exception No 2: Environmental testing on a subassembly may be conducted instead of the complete ESS if through analysis it can be determined to be representative of the ESS. The rationale used to determine the suitability of the subassembly to represent the complete ESS shall be documented.*	Evaluated for moisture exposure and marine environments.	P
41.2	Outdoors installations subject to moisture exposure	Complied.	P
41.2.1	Energy storage systems intended for installation outdoors where they will be subject to rated levels of moisture exposure shall be tested in accordance with their environmental ratings outlined in their nameplate labels and installation instructions of 45.17 and 46.13.	Compliance to IPX5	P
41.2.2	Based upon the ratings of the system, moisture resistance testing shall be done in accordance with either IEC 60529, UL 50E, or C22.2 No. 94.2.	Used IEC60529 method.	P
41.2.3	At the conclusion of the test, the sample is to be subjected to the electric insulation tests of Sections 32 and 35 and examined for signs of water in the system that could result in a hazardous condition.	Complied.	P
41.2.4	As a result of the water exposure, there shall be no evidence of water on parts that could result in a hazard and no reduction of spacings or breakdown/deterioration in insulation levels.	Complied.	P
41.3	Outdoor installation in marine environments	Complied.	P
41.3.1	Energy storage systems intended for installation outdoors in marine environments in accordance with the installation instructions in 46.13 where they will be subject to salt fog exposure, shall be tested as outlined below.		P
41.3.2	The systems shall be tested in accordance with IEC 60068-2-52 for Severities 1 or 2.	Applied Severity 2.	P
41.3.3	At the conclusion of the testing, the systems shall be subjected to the electrical insulation tests of Sections 32 and 35 to determine that insulation has not been damaged in a manner that would result in an electric shock hazard.	Complied.	P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
41.3.4	The system shall be examined for signs of damage as a result of salt exposure that would indicate a potential for a safety hazard (e.g. corrosion of parts that could result in weakening of a securement or an enclosure, damage to insulation). If operational, the system is to be operated to determine that it can do so without hazard.	Complied. Rechargeable Li-ion battery system was operational and remined intact after test.	P
41.3.5	As a result of the test, the ESS shall not show evidence of damage from salt fog exposure that could result in a hazard such as electrical, shock, overheating or damage that could result in a physical hazard.	Complied.	P
41.4	Installation in seismic environments	Optional. Not applied.	N/A
41.4.1	Equipment of an ESS that contains the energy storage mechanism and is intended for installation where they will be subject to seismic activity shall be evaluated and if necessary tested in accordance with their seismic ratings and installations instructions per 45.3 and 46.13. The installation instructions shall indicate the limitations of the particular seismic rating of the equipment. Standards that provide guidance on seismic evaluation such as IEEE 693, IEC 60980, ICC IBC, the seismic testing in GR-63-CORE, or similar, shall be used for this evaluation. Compliance is determined through review of documentation of the seismic evaluation for the appropriate seismic level (i.e. level marked on the equipment) or through testing for the specific seismic level in accordance with a testing standard for this purpose. *Exception No. 1: There is equipment that cannot be practically evaluated by testing alone because of the size of the equipment. For those situations, it may be necessary to do a combination of analysis with testing of parts of the system. This approach is outlined in IEEE 344.* *Exception No. 2: Some standards allow for calculations and modelling as an approach for determining compliance for seismic ratings in lieu of testing.*		N/A
41.4.2	The ESS shall be examined for signs of explosion, fire, combustible concentrations (if applicable to technology), rupture of the enclosure, electrolyte leakage, electric shock and loss of protection controls that lead to any of the other non-compliant results in 41.4.3.		N/A

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
41.4.3	As a result of the test, any of the following results in (a) – (g) are considered a non-compliant result: a) Explosion; b) Fire; c) Combustible Concentrations (if applicable to technology); d) Rupture (enclosure); e) Electrolyte Leakage (external to enclosure); f) Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown); g) Loss of protection controls.		N/A
	MANUFACTURING AND PRODUCTION TESTS		P
42	Electrical Production Tests	Complied via UL Follow-Up services. It needs to be maintained continuously for validity of product certification.	P
42.1	Dielectric voltage withstand test	See above.	P
42.1.1	A dielectric withstand test as outlined in the Dielectric Voltage Withstand Test in Section 32 shall be conducted on 100 % production of ESS with working voltage exceeding 60 Vdc or 30 Vrms/42.4 Vpeak. *Exception No. 1: The time for the production Dielectric Withstand Test can be reduced to 1 s.* *Exception No. 2: Testing can be conducted on subassemblies of the system.* *Exception No. 3: Testing can be waived if conducted as part of the specific technology evaluation (i.e. tested per UL 1973, etc.)*	See above.	P
42.2	Grounding and bonding system check	Complied via UL Follow-Up services. It needs to be maintained continuously for validity of product certification.	P
42.2.1	The grounding and bonding system of an ESS shall be subjected to a check using an impedance measuring device. The measurements shall occur between any two locations of the grounding and bonding system.	See above.	P
42.2.2	No resistance measurements of the grounding and bonding system shall exceed 0.1 Ω or allowed limits per 34.2. *Exception: This testing can be waived if it is determined that the ESS construction and production methods to ensure good grounding and bonding of the system production can be determined through a review of production practices. However, if any point of the grounding system is maintained through a single fastener, a ground bond test shall be conducted.*	See above.	P

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
42.3	Check of safety controls	Complied via UL Follow-Up services. It needs to be maintained continuously for validity of product certification.	P
42.3.1	Energy storage systems shall be subjected to 100 % production screening to determine that any active controls utilized for safety are functioning. *Exception: This check of the safety controls can be conducted on subassemblies or components of the system before final assembly.*	Firmware version and unique identifier of chiller shall be checked during manufacturing.	P
43	Mechanical Production Tests	No mechanical production test is applicable.	N/A
43.1	Integrity at maximum abnormal operating speed		N/A
43.1.1	Every production mechanical storage element shall be subjected to a maximum abnormal operating speed test. The test shall be performed at the maximum speed reached during the Overspeed Test of 37.1. The test shall be performed in an environment which will safely contain any mechanical failure of the mechanical storage element.		N/A
43.1.2	As an alternative to 43.1.1, the components of a mechanical energy storage element (e.g. forged disk) shall be processed consistently and tested to ensure that the materials used in its construction meet the minimum requirements assumed during the design and analysis of the element. The engineering development and production testing protocol for the components of the energy storage element shall demonstrate the level of uniformity of the material properties throughout critical sections of the component and that the material properties meet required minimum values consistently.		N/A
43.2	Production screening of rotors		N/A
43.2.1	Rotor assemblies for mechanical ESS shall be subject to 100 % production screening through the use of non-destructive testing or other means to check for cracks and other flaws. Any cracks or flaws found shall be evaluated in accordance with manufacturer’s specifications.		N/A
43.2.2	As an alternative to 43.2.1, additional in progress quality checks and testing can be incorporated into the manufacturing assembly process to limit the presence of cracks or flaws in finished product. Refer to 44.1.		N/A
43.3	Leak check of hazardous fluid systems		N/A
43.3.1	ESS that contain hazardous fluids including ESS with liquid coolant systems shall be subjected to a leak check in accordance with Section 38 of the assembled fluid containment system.		N/A

ANSI/CAN/UL9540:2020			
Clause	Requirement + Test	Result - Remark	Verdict
44	Production Quality Control	Complied via UL Follow-Up services. It needs to be maintained continuously for validity of product certification.	P
44.1	Manufacturers of ESS shall have documented production process controls in place that continually monitor the following key elements of the manufacturing process that can affect safety, and shall include measured parametric limits enabling corrective/preventative action to address defects (out of limit parameters) found affecting these key elements: a) Supply chain control; and b) Assembly processes.	See above.	P
	MARKINGS		P
45	General	Complied.	P
	INSTRUCTIONS		P
46	General	Checked compliance of provided documents of Installation, Operation and Maintenance Manuals.	P
	Appendix B.		P
	General Battery Safety Consideration	Complied.	P
	Appendix C.		P
	Safety Marking Translations	Safety markings but no Canadian deviation(use of French language for safety marking) was considered.	P
	APPENDIX D.		N/A
	Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Battery Systems	Rechargeable Li-ion Battery Systems.	N/A
	APPENDIX E.		N/A
	Guidance On Capacity and Separation Distance Limits for Electrochemical ESS	Commercial and Industrial outdoor application. Installation shall follow the code and local regulations.	N/A
	APPENDIX G.		N/A
	CLEAN AGENT DIRECT INJECTION BATTERY RACK COOLANT SYSTEM UNITS	N/A	N/A
	APPENDIX H.		N/A
	MANUFACTURER’S INSTALLATION INSTRUCTIONS TEMPLATE FOR RESIDENTIAL ESS	Non-Residential Application.	N/A

-**End of Letter Report-**

Appendix 2-C: Fire and Safety Reports for DC LINK Batteries

UL1973

- [UL1973] JF2 NoA_240705
- F2D4-5.1US-CC08_DC Rack Certificate UL 1973_V1.0 (NOA)
- F2D4-5.1US-CC09_DC Rack Test Report UL 1973_V1.0
- F2X4-5.1US-CC04_Cell Certificate UL 1973_V1.0
- F2X4-5.1US-CC05_Cell Test Report UL 1973_V1.0
- F2X4-5.1US-CC06_Pack Certificate UL 1973_V1.0 (NOA)
- F2X4-5.1US-CC07_Pack Test Report UL 1973_V1.0

Safety. Science. Transformation.™

2024-07-05

Taecheon Kim
LG Energy Solution, LTD.
188, Munji-ro, Yuseong-gu
Daejeon, 34122, KR

Notice of Completion (NoC) and authorization to apply the UL Mark

Your reference:		
Our reference:	File MH63736, Volume 1	Order: 15284234 Project: 4791298454

Project scope: USR/CNR - ANSI/CAN/UL1973:2022 Annex E,
Rechargeable Li-ion Cell, Model : JF2 in Vol1. Sec.25

Dear Taecheon Kim:

We appreciate that you have a choice of certification providers and thank you for choosing UL Solutions**.**
We have completed the investigation under the above project and confirmed compliance of your product(s) with UL Mark requirements.

This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark at the factory location(s) identified on the Authorization Page of UL Solutions File MH63736, Volume 1. You are required to send a copy of this letter to all manufacturing locations authorized under UL Solutions File MH63736, Volume 1.

The Follow-Up Services Procedure covering your product(s) will typically be provided by UL Solutions within 10 business days. Any information and documentation provided to you involving the UL Mark services are provided on behalf of UL LLC or any authorized licensee. The UL Solutions certification directory is updated with active certifications shortly after projects are reviewed and completed. Please visit https://productiq.ulprospector.com/ to search for the certification.

Products that bear the UL Mark must be identical to those submitted to UL for evaluation and certification and must comply with the Follow-Up Services Procedure covering your product(s). Additional requirements related to the responsibilities of the Applicant and Manufacturer can be found under **Customer Requirements documents** at www.ul.com/fus.

A UL Solutions certification is a valuable marketing tool meaning your product or company has successfully met stringent requirements. We encourage you to use your UL Mark and certification in your marketing activities. We are happy to provide guidance on how best to promote your UL certification. Our Certification Achievement Kit demonstrates marketing and promotional concepts to help you best represent your UL certification.

UL Solutions is committed to providing you with an exceptional customer experience. You may receive an email from ULSurvey@feedback.ul.com inviting you to provide feedback. Your survey rankings and comments regarding the experience are important to us. We are always seeking ways to improve in any areas we can, and your feedback and comments are vital to this process.

If you have any questions, please contact me or any of our customer service representatives at www.ul.com/contact-us.

Sincerely,

Richard Jeon
Senior Project Engineer
UL Solutions
Richard.Jeon@ul.com

David Piecuch
UL Mark Certification Program Manager
UL LLC
David.Piecuch@ul.com

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Safety. Science. Transformation.™

Hyeon Kyu Kim
LG Energy Solution, LTD.
188, Munji-ro, Yuseong-gu
Daejeon, 34122, KR

Notice of Completion (NoC) and authorization to apply the UL Mark

Your reference:	File MH49414, Volume 1	
Our reference:	File MH49414, Volume 1	Order: 15411957 Project: 4791415432

Project scope: [BBFX2/8, MH49414] JF2 Battery System (Rack). UL1973 Basic_JF2 (incl.travel cost) model. NR27N414L_P15190NB3

Dear Hyeon Kyu Kim:

We appreciate that you have a choice of certification providers and thank you for choosing UL Solutions**.**
We have completed the investigation under the above project and confirmed compliance of your product(s) with UL Mark requirements.

This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark at the factory location(s) identified on the Authorization Page of UL Solutions File MH49414, Volume 1. You are required to send a copy of this letter to all manufacturing locations authorized under UL Solutions File MH49414, Volume 1.

The Follow-Up Services Procedure covering your product(s) will typically be provided by UL Solutions within 10 business days. Any information and documentation provided to you involving the UL Mark services are provided on behalf of UL LLC or any authorized licensee. The UL Solutions certification directory is updated with active certifications shortly after projects are reviewed and completed. Please visit https://productiq.ulprospector.com/ to search for the certification.

Products that bear the UL Mark must be identical to those submitted to UL for evaluation and certification and must comply with the Follow-Up Services Procedure covering your product(s). Additional requirements related to the responsibilities of the Applicant and Manufacturer can be found under **Customer Requirements documents** at www.ul.com/fus.

A UL Solutions certification is a valuable marketing tool meaning your product or company has successfully met stringent requirements. We encourage you to use your UL Mark and certification in your marketing activities. We are happy to provide guidance on how best to promote your UL certification. Our Certification Achievement Kit demonstrates marketing and promotional concepts to help you best represent your UL certification.

UL Solutions is committed to providing you with an exceptional customer experience. You may receive an email from ULSurvey@feedback.ul.com inviting you to provide feedback. Your survey rankings and comments regarding the experience are important to us. We are always seeking ways to improve in any areas we can, and your feedback and comments are vital to this process.

If you have any questions, please contact me or any of our customer service representatives at www.ul.com/contact-us.

Sincerely,

Donghyun Kim
Engineer Project Associate
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Donghyun.Kim@ul.com

David Piecuch
UL Mark Certification Program Manager
UL LLC
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16d6c4dac1a74d6dabbeb9ac16f11dc7

TEST RECORD NO. 1

SAMPLES:

A sample of the battery system as indicated below and constructed as described herein, was submitted by the manufacturer for examination and test.

EESS ELECTRICAL RATING:

Battery system Model	Use Limitations	Voltage (Nominal), Vdc	Capacity (Nominal), Ah/~~Wh~~, Farad	Enclosure IP Rating
NR27N414L_P15190NB3	Indoor intended for use in end applications	1344	636.8	IP20 (No-Enclosure Type)
Note: Representative of the Battery system models, NR27N414L_P15190NB3, has been tested based upon their electrical ratings, but no capacity performance testing has been conducted.				

MANUFACTURER'S RECOMMENDED CHARGING PARAMETERS:

Battery System Model	Temperature Range, °C	Maximum Charging Voltage, Vdc	Normal Charging Voltage, Vdc	Maximum Charging Power, kW	Normal Charging Current, A
NR27N414L_P15190NB3	0.0 to 40.0	1499.4	1499.4	213.962 (Peak current 188.67 A at End of Discharge Voltage)	N/A

MANUFACTURER'S RECOMMENDED DISCHARGE PARAMETERS:

Battery System Model	Temperature Range, °C	End of Discharge Voltage, Vdc	Maximum Discharging Power, kW	Normal Discharging Current, A
NR27N414L_P15190NB3	0.0 to 40.0	1134.0	213.962 (Peak current 188.67 A at End of Discharge Voltage)	N/A

MANUFACTURER’S SPECIFIED NORMAL OPERATING REGION FOR CELL:

Battery module Model	Cell Model (File NO.)	Operating Ambient Temperature Range, °C	Upper Limit of Charging Voltage, Vdc	Upper Limit of Charging Current, A	Upper Limit of Discharge Current, A	Discharge Voltage Cutoff, Vdc	Upper Limit of Cell Temperature, °C
NR27N414L_P15190NB3	JF2 (MH63736)	Charging: (0 to 45) Discharging: (0 to 45)	4.1	141.5	141.5	1.8	Charging: (-30.0 to 75.0) Discharging: (-30.0 to 75.0)

Model Differences:

N/A

GENERAL:

NR27N414L_P15190NB3 is considered as a representative model for tests.

Test results relate only to the items tested

1. Datasheet 1 for tests conducted at UL Changzhou Quality Technology Services Co., Ltd (Party Site Number: 2317149).:

OVERCHARGE TEST	UL 1973, Sec. 15
HIGH RATE CHARGE TEST	UL 1973, Sec. 16
SHORT CIRCUIT TEST	UL 1973, Sec. 17
OVERLOAD UNDER DISCHARGE TEST	UL 1973, Sec. 18
OVERDISCHARGE PROTECTION	UL 1973, Sec. 19
TEMPERATURE AND OPERATING LIMITS CHECK TEST	UL 1973, Sec. 20
IMBALANCED CHARGING TEST	UL 1973, Sec. 21
DIELECTRIC WITHSTAND TEST	UL 1973, Sec. 22
FAILURE OF COOLING/THERMAL STABILITY TEST	UL 1973, Sec. 24
WORKING VOLTAGE MEASUREMENTS	UL 1973, Sec. 25

2. Datasheet 2 for tests conducted at UL Changzhou Quality Technology Services Co., Ltd (Party Site Number: 2317149).:

~~WALL MOUNT FIXTURE~~/SUPPORT STRUCTURE/~~HANDLE TEST~~	UL 1973, Sec. 26.6

3. Datasheet 3 for tests conducted at HCT Co., Ltd (Party Site Number: 548239).

The following tests were conducted on the battery protection unit, P15190NB3.:

STATIC FORCE TEST	UL 1973, Sec. 15
IMPACT TEST	UL 1973, Sec. 16
DROP IMPACT TEST	UL 1973, Sec. 17
~~WALL MOUNT FIXTURE/SUPPORT STRUCTURE~~/HANDLE TEST	UL 1973, Sec. 18

4. Datasheet 4 for tests conducted at One Energy Solution Inc. (Party Site Number: 3601674).

This test was conducted again because there were modifications on the battery protection unit, P15190NB3, after Datasheet 1.:

The following test was only required to evaluate the modifications by engineer consideration. Refer to Ill. 4 in the test reference for the detail of the modifications.

TEMPERATURE AND OPERATING LIMITS CHECK TEST	UL 1973, Sec. 20

The test methods and results of the above tests have been reviewed and found in accordance with the requirements in the Third Edition of ANSI/CAN/UL-1973, Batteries for Use in Stationary and Motive Auxiliary Power Applications, issued on February 25, 2022.

The following tests were not deemed necessary:

Test not to be Conducted	UL 1973 Section	Comments
Continuity Test	23	There is no protective grounding and bonding system since the rack frame was tentative to run the test. It will be evaluated in end use application.
Locked-rotor test for low voltage dc fans/motors in secondary circuits	26.1	Fan has complied with UL507.
Input	26.2	The battery does not have mains supplied control or accessory.
Leakage	26.3	The battery does not have mains supplied control or accessory.
Strain Relief Test	26.4	The battery does not have a cord.
Push-back Relief Test	26.5	No resettable pressure relief valve.
Electromagnetic Immunity Tests	27	It will be evaluated in end use application.
Vibration Test	28	Only for LER application
Shock Test	29	Only for LER application
Crush Test	30	Only for LER application
Static Force Test	31	The battery system is not installed and transported in an assembled status.
Impact Test	32	The battery system is not installed and transported in an assembled status.
Drop Impact Test	33	The battery system is not installed and transported in an assembled status.
Mold Stress Test	35	There are no polymeric parts exposed outside.
Pressure Release Test	36	No resettable pressure relief valve.
Start-To-Discharge Test	37	No resettable pressure relief valve.
Thermal Cycling	38	Only for LER application.
Resistance to Moisture Test	39	It will be installed indoors.
Salt Fog Test	40	It will be installed indoors.
External Fire Exposure Test	41	Component Cell complied with Projectile Test which is in Annex E of UL 1973.
Test program for sodium-beta battery cells	Appendix B	Lithium-ion cells are used.
Test program for flowing electrolyte batteries	Appendix C	Lithium-ion cells are used.

Test Record Summary:

The results of this investigation indicate that the products evaluated comply with the applicable requirements in the third Edition of ANSI/CAN/UL-1973, Batteries for Use in Stationary and Motive Auxiliary Power Applications, issued on February 25, 2022. Therefore, such products are judged eligible to bear UL’s Mark as described on the Conclusion Page of this Report.

CONCLUSION

A sample of the component covered by this Report has been found to comply with the requirements covering the category and the component is found to comply with UL's applicable requirements. The description and test result in this Report are only applicable to the sample(s) investigated by UL and does not signify the product(s) described as being covered under UL's Follow-Up Service Program. When covered under UL's Follow-Up Service Program, the manufacturer is authorized to use the Recognized Marking on such products which comply with UL's Follow-Up Service Procedure and any other applicable requirements of UL LLC. The Recognized Component Mark of UL LLC on the product, or the Recognized Marking symbol on the product and the Recognized Component Mark on the smallest unit container in which the product is packaged, is the only method to identify products investigated by UL to published requirements and manufactured under UL's Recognition and Follow-Up Service.

Report by:	Reviewed by:
Donghyun Kim	Leon Lee
Engineer Project Associate	Senior Project Engineer

Certificate of Compliance

Certificate Number:

UL-US-2426857-0

Report Reference:

MH63736-20240705

Issue Date:

2024-07-09

Issued to:

LG Energy Solution, LTD.
188, Munji-ro, Yuseong-gu Daejeon 34122
Republic of Korea

This certificate confirms that representative samples of:

BBGA2 - Battery Cells for Use in Stationary and/or Transport Applications - Component

See Addendum Page for Product Designation(s).

Have been evaluated by UL in accordance with the component requirements in the Standard(s) indicated on this Certificate. UL Recognized components are incomplete in certain constructional features or restricted in performance capabilities and are intended for installation in complete equipment submitted for investigation to UL LLC.

ANSI/CAN/UL 1973:2022, 3rd Ed., Issue Date: 2022-2-25

Additional Information:
See UL Product iQ® at https://iq.ulprospector.com for additional information.

This Certificate of Compliance indicates that representative samples of the product described in the certification report have met the requirements for UL certification. It does not provide authorization to apply the UL Recognized Component Mark. Only the Authorization Page that references the Follow-Up Services Procedure for ongoing surveillance provides authorization to apply the UL Mark.

Only those products bearing the UL Recognized Component Mark should be considered as being UL Certified and covered under UL's Follow-Up Services.

Look for the UL Recognized Component Mark on the product.

David Piecuch
UL Mark Certification Program Manager

UL Solutions

CERTIFICATE OF COMPLIANCE

Certificate number UL-US-2426857-0
Report reference MH63736-20240705
Date 2024-07-09

This is to certify that representative samples of the product as specified on this certificate were tested according to the current UL requirements.

Model	Product Description
JF2	Stationary or Transport Applications Battery Cells

David Piecuch
UL Mark Certification Program Manager

Certificate of Compliance

Certificate Number:

UL-CA-2421073-0

Report Reference:

MH63736-20240705

Issue Date:

2024-07-09

Issued to:

LG Energy Solution, LTD.
188, Munji-ro, Yuseong-gu Daejeon 34122
Republic of Korea

This certificate confirms that representative samples of:

BBGA8 - Battery Cells for Use in Stationary and/or Transport Applications Certified for Canada - Component

See Addendum Page for Product Designation(s).

Have been evaluated by UL in accordance with the component requirements in the Standard(s) indicated on this Certificate. UL Recognized components are incomplete in certain constructional features or restricted in performance capabilities and are intended for installation in complete equipment submitted for investigation to UL LLC.

ANSI/CAN/UL 1973:2022, 3rd Ed., Issue Date: 2022-2-25

Additional Information:
See UL Product iQ® at https://iq.ulprospector.com for additional information.

This Certificate of Compliance indicates that representative samples of the product described in the certification report have met the requirements for UL certification. It does not provide authorization to apply the UL Recognized Component Mark. Only the Authorization Page that references the Follow-Up Services Procedure for ongoing surveillance provides authorization to apply the UL Mark.

Only those products bearing the UL Recognized Component Mark should be considered as being UL Certified and covered under UL's Follow-Up Services.

Look for the UL Recognized Component Mark on the product.

David Piecuch
UL Mark Certification Program Manager

UL Solutions

CERTIFICATE OF COMPLIANCE

Certificate number UL-CA-2421073-0
Report reference MH63736-20240705
Date 2024-07-09

This is to certify that representative samples of the product as specified on this certificate were tested according to the current UL requirements.

Model	Product Description
JF2	Stationary or Transport Applications Battery Cells

David Piecuch
UL Mark Certification Program Manager

TEST RECORD NO. 1

SAMPLES:

A sample of the JF2 as indicated below and constructed as described herein, was submitted by the manufacturer for examination and test.

Model	Cell Chemistry	Cell Shape	Nominal Voltage Rating, V dc	Capacity, Ah
JF2	$LiFePO_4+C_6 \Leftrightarrow LiC_6+FePO_4$	Pouch	3.2	159.2

GENERAL:

Test results relate only to the items tested.

The following tests were conducted:

Test	Test location	Complied, Y, N Or N/A
E2 CAPACITY CHECK	NCT Co., Ltd	Y
E3 SHORT CIRCUIT	NCT Co., Ltd	Y
E4 CELL IMPACT	LG Energy solution	Y
E5 DROP IMPACT	NCT Co., Ltd	Y
E6 HEATING	NCT Co., Ltd	Y
E7 OVERCHARGE	NCT Co., Ltd	Y
E8 FORCED DISCHARGE	NCT Co., Ltd	Y
E9 PROJECTILE	NCT Co., Ltd	Y

Tests with test location marked with “NCT Co., Ltd” in above table were conducted at NCT Co., Ltd., addressed 211-71, Geumgok-ro, Hwaseong-si, Gyeonggi-do, 18511, Republic of Korea and LG Energy solution addressed 81, 2sandan-ro, Ocahng-eup, Cheonwon-gu, Cheongju-si Chungcheonbuk-do, 28117 under WTDP program.

The test methods and results of the above tests have been reviewed and found in accordance with the requirements in the Standard for ANSI/CAN/UL 1973:2022, Batteries for Use in Stationary and Motive Auxiliary Power Applications, Edition 3, Issue Date 02/25/2022.

Test Record Summary:

The results of this investigation, including construction review and testing, indicate that the products evaluated comply with the applicable requirements in ANSI/CAN/UL 1973:2022, Batteries for Use in Stationary and Motive Auxiliary Power Applications, Edition 3, Issue Date 02/25/2022 and, therefore, such products are judged eligible to bear UL's Mark as described on the Conclusion Page of this Report.

Per Standard No.	ANSI/CAN/UL 1973	Edition/ Latest Revision Date	3rd/ 2022-02-25

CONCLUSION

Samples of the component covered by this Report have been found to comply with the requirements covering the category and the are found to comply with UL’s applicable requirements. The description and test result in this Report are only applicable to the sample(s) investigated by UL and does not signify the product(s) described as being covered under UL’s Follow-Up Service Program. When covered under UL’s Follow-Up Service Program, the manufacturer is authorized to use the Recognized Marking on such products which comply with UL’s Follow-Up Service Procedure and any other applicable requirements of UL LLC. The Recognized Component Mark of UL LLC on the product, or the Recognized Marking symbol on the product and the Recognized Component Mark on the smallest unit container in which the product is packaged, is the only method to identify products investigated by UL to published requirements and manufactured under UL’s Recognition and Follow-Up Service.

Report by:	Reviewed by:
Richard Jeon Senior Project Engineer	MyungAh Lim Senior Project Engineer

Hyeon Kyu Kim
LG Energy Solution, LTD.
188, Munji-ro, Yuseong-gu
Daejeon, 34122, KR

Notice of Completion (NoC) and authorization to apply the UL Mark

Your reference:	File MH49414, Volume 1	
Our reference:	File MH49414, Volume 1	Order: 15402464 Project: 4791407191

Project scope: [BBFX2/8, MH49414] JF2 Module(Pack). UL1973 Basic_JF2 Model. EP096636PFB1

Dear Hyeon Kyu Kim:

We appreciate that you have a choice of certification providers and thank you for choosing UL Solutions**.**
We have completed the investigation under the above project and confirmed compliance of your product(s) with UL Mark requirements.

This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark at the factory location(s) identified on the Authorization Page of UL Solutions File MH49414, Volume 1. You are required to send a copy of this letter to all manufacturing locations authorized under UL Solutions File MH49414, Volume 1.

The Follow-Up Services Procedure covering your product(s) will typically be provided by UL Solutions within 10 business days. Any information and documentation provided to you involving the UL Mark services are provided on behalf of UL LLC or any authorized licensee. The UL Solutions certification directory is updated with active certifications shortly after projects are reviewed and completed. Please visit https://productiq.ulprospector.com/ to search for the certification.

Products that bear the UL Mark must be identical to those submitted to UL for evaluation and certification and must comply with the Follow-Up Services Procedure covering your product(s). Additional requirements related to the responsibilities of the Applicant and Manufacturer can be found under **Customer Requirements documents** at www.ul.com/fus.

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If you have any questions, please contact me or any of our customer service representatives at www.ul.com/contact-us.

Sincerely,

Donghyun Kim
Engineer Project Associate
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Donghyun.Kim@ul.com

David Piecuch
UL Mark Certification Program Manager
UL LLC
David.Piecuch@ul.com

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JF2 Pack Test Report UL9540A

Document No: F2X4-5.1US-CT10

Model: JF2 Pack

Revision History

Version	Date	Author	Description
1.0	Jun. 28, 2024	Kyungmin Lee	Initial release

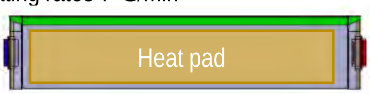
❑ Module Level UL9540A Test (Internal)

- Internal test shows that new JF2 design can comply with the unit level UL9540A test criteria

Test scenarios

[UL9540A Thermal Runway Methodology]

- Attach flexible heat pad, double side
- Heating rates 7℃/min



[Test criteria]

- Following UL9540a test standard (Unit level)
  - No explosion hazards exhibited by product
  - No flaming beyond outer dimensions of BESS unit (indoor, wall mount).
- Aims to no flame, no T/P on to the next cell unit and next module (LGES target)

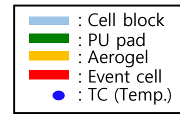
[UL9540a solutions]

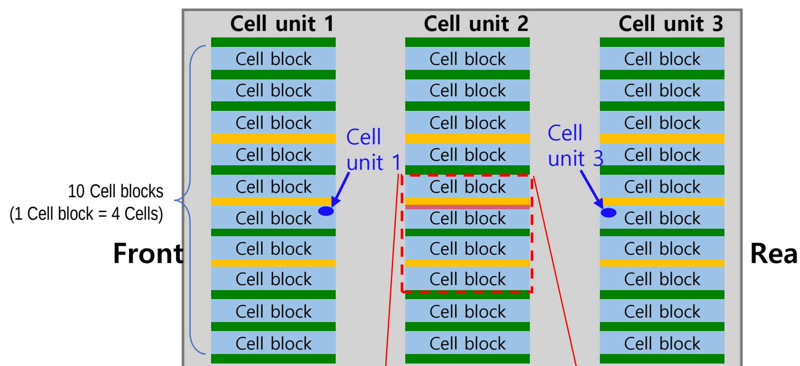
- Between cell units:- 8ea Pad (5.0mm)
  - 3 thermal barrier
  - Optimized air insulation space

Test set up

[Test samples]

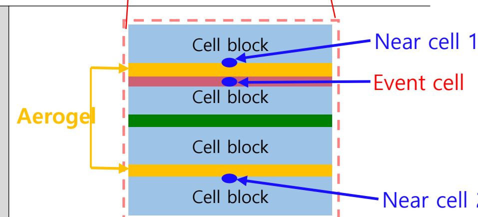
- Cell used : JF2 (123.5x600x17.7mm, 159.2 Ah min.)





<Top view>

[Cell unit set up]

Initiating cell (location)	
Heat film (location)	Double sided (UL9540A 4th edition test method)
Event cell unit config.	10S4P

Test Result

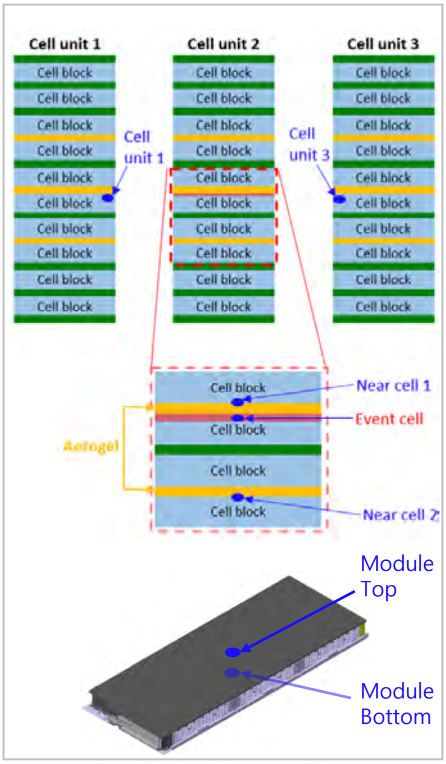
- Max temp cell (Initiating cell unit) : 970.1°C
- Thermal Propagation cells : 8ea / 120cell

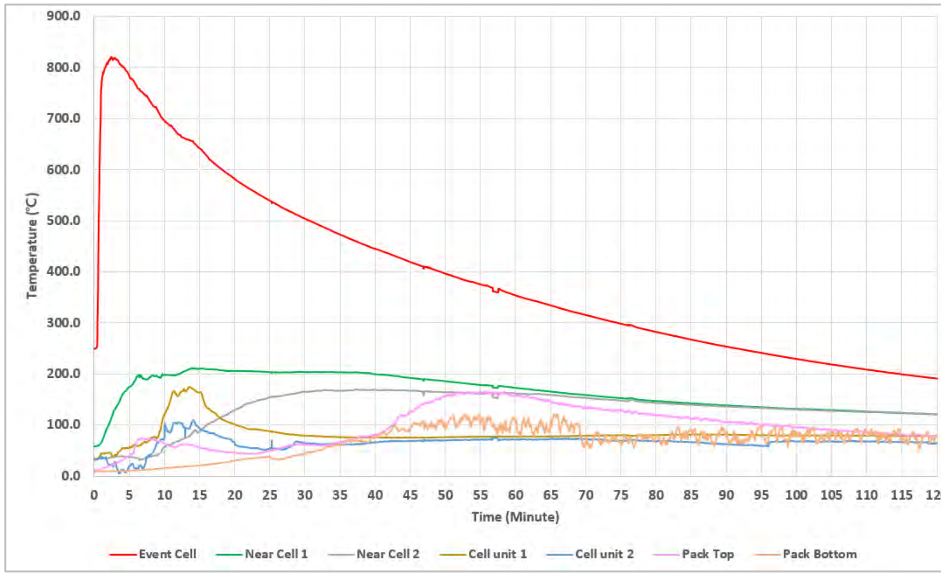
Flame occurrence	No
T/P on to next cell unit	No
T/P on to next Module	No
UL9540A standard at Unit level	Pass

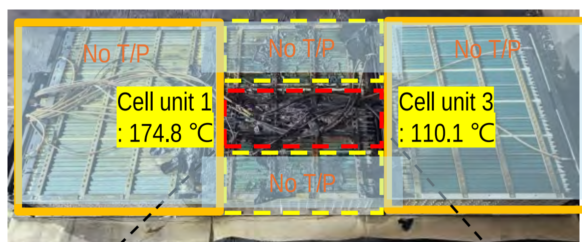
❑ Module Level UL9540A Test (Internal)

- No thermal runaway propagation beyond the thermal barrier inside the sub-module.

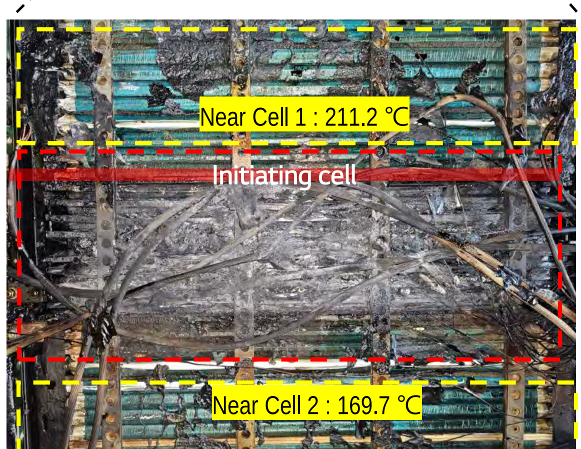
[Event cell unit : 8 cells were propagated, leaving 32 cells without propagation]







Test sample (after test)



Event cell unit

❑ Thermal Runaway propagation prevention (Internal Module Level UL9540A Test)

- When thermal runaway occurred, the total amount of gas is about 66.3L.
- Total amount of gas after cycle test (SOH 70%) is about 40% of the gas that the pouch can endure before venting.

1 Gas Analysis when Thermal Runaway occurred

Conditions : Analysis of the generated gas when thermal runaway occurred in the vacuum chamber according to UL9540A Cell level test conditions.

Cell retention	BOL	
Type of Gas	Gas Volume	
	(L)	(v/v %)
H_2	44.7	67.4
CO	3.0	4.5
CO_2	9.9	14.9
CH_4	3.9	5.9
C_2H_2	0.1	0.2
C_2H_4	3.5	5.3
C_2H_6	0.7	1.1
C_3H_6	0.3	0.4
C_3H_8	0.1	0.2
Total	66.3	100

2 Gas Analysis Results of Cycle Test Cell

Conditions : Analysis of the gas after cycle test (without thermal runaway)

Cell Retention	70%
Total amount of Gas[mL]	183.8

■ Gas Injection Test

	Cell Pressure at Vent(bar)	Injected Gas Amount at Vent(mL)
JF2 Sample	4.76	461.0

※ Gas injection Test Conditions

- SOC level : 0%
- Temp. : 25°C
- Gas : He gas
- Flow rate : 5sccm
- Initial point : 1bar

Appendix 2-C: Fire and Safety Reports for DC LINK Batteries

Fire Protection

- F2XX-5.1US-FS09_AC&DC LINK Fire Alarm System Drawing_V5.0

LG Energy Solution

Confidential

Fire Alarm System Drawing

JF2 DC/AC LINK 5.1

Document No :	F2X4-5.1US-FS09
Revision :	5.0

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1. Introduction

This document describes the fire Alarm System of JF2 DC/AC LINK 5.1. The JF2 DC/AC LINK 5.1 consists of three M-LINKs and one E-Panel. The total capacity is 5.11MW and the voltage range is 1,134~1,499.4V. For detailed specifications, please refer to Table 1 and 2 below.

Item	Specification
Cell	JF2
Pack	4P30S
Rack	14Pack in series per Rack
Configuration	6Rack system per DC LINK
Voltage (Nominal)	1344Vdc
DC Voltage Range	1,134~1,499.4 Vdc
Energy Density	5.11 MWh
Communication	Modbus TCP/IP(Ethernet, Optical)
Auxiliary Power	AC480 3Phase 60Hz

Table 1. JF2 DC/AC LINK 5.1 Electrical Specification

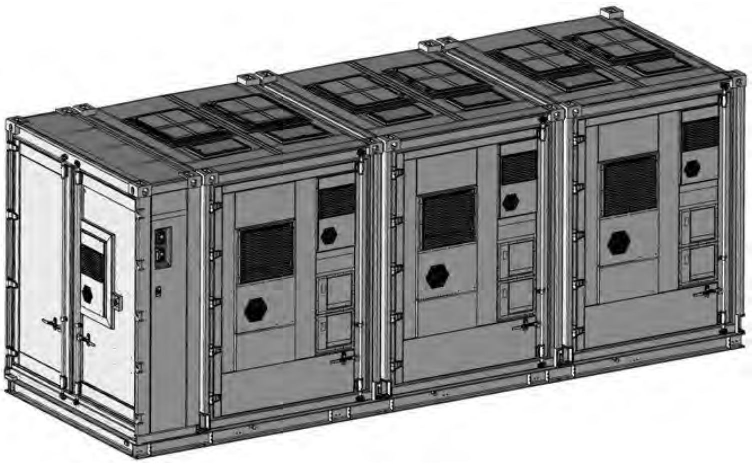
Item	Specification
Appearance	
Dimension (W×D×H,mm)	7,170 x 2,570 x 2,896mm
Weight	about. 48 ton
Ingress protection level	55
Cooling	Liquid Cooling
Seismic grade	ASCE(7-22) Sds1.2 (optional Sds 1.5)
Transportable	O (with pre-installation)
Explosion proof	O (Active Ventilation)
Certification	UL1642, UL1973, FCC, UL9540A, UL9540, UN38.3, UN3536, UL1741, NFPA 69,72,855

Table 2. JF2 DC/AC LINK 5.1 Mechanical Specification

1.1 Fire Safety Design Overview

The DC LINK 5.1 system complies with the standards NFPA 69, NFPA 72, UL 268, UL 2075, UL 864, UL 1973, and UL 9540A. The E-panel is equipped with an FACP (Fire Alarm Control Panel), a smoke detector and 2 horn & strobe devices ("for gas" and "for fire"). Each M-LINK is equipped with a smoke detector and a gas detector. The signals detected by the M-LINK are transmitted to the FACP located in the E-panel, and the FACP send the information to the FCC (Fire Command Center).

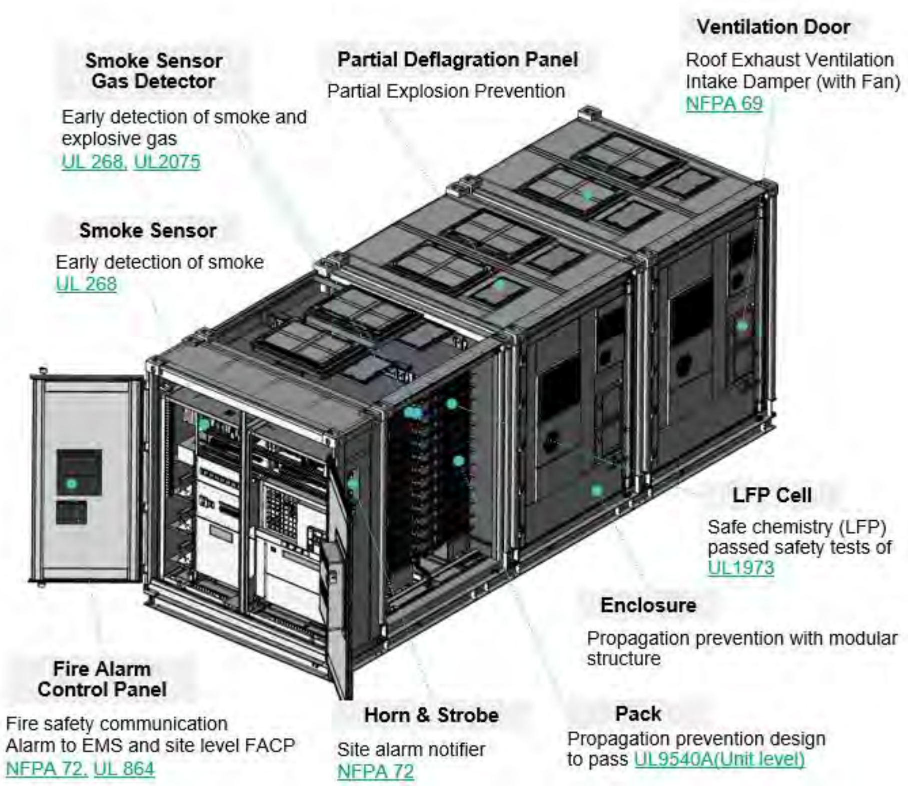


Figure 1. Fire Safety Design Overview

Item		Key components
Cell		LFP chemistry. Passed safety tests including short circuit, nail, and impact tests
Pack		Thermal insulation to prevent Sub-Pack to Sub-Pack thermal propagation
Enclosure		Modular structure to help preventing enclosure to enclosure propagation
Explosion Prevention		Ventilation Door on the roof / Partial Deflagration Panel / Intake Damper (with Fan)
FSS	Detection	Gas (H2) detector, Smoke sensor
	Alarm	Fire Alarm Control Panel & Horn & Strobe (2ea in E-Panel, Gas & Smoke)

Table 3. Fire Safety Design Overview

2. Component Specification

2.1 E-Panel Fire Safety Components

The table below lists the fire safety materials installed in the E-Panel.

2.1.1 Horn and Strobe (Smoke)

The brightness of Horn and Strobe (Smoke) is usually set as 75cd. Tone pattern for Horn and Strobe (Smoke) is usually temporal and the volume of sound is 85db which is pattern 1 of figure 2. Brightness and tone pattern can be changed depending on site's property. Those can be set by turning the dial of Horn and Strobe (Smoke). Refer to figure 2.

Wattage of Horn and Strobe (Smoke) is 2.088[W] when brightness is set as 75cd. It can vary by the brightness.

2.1.2 Horn and Strobe (Gas)

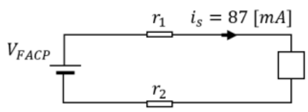
The brightness of Horn and Strobe (Gas) is usually set as 75cd. Tone pattern for Horn and Strobe (Gas) is usually non-temporal and the volume of sound is 85db or 77db which are pattern 3 or 4 of figure 2. Brightness and tone pattern can be changed depending on site's property. Those can be set by turning the dial of Horn and Strobe (Gas). Refer to figure 2.

Wattage of Horn and Strobe (Gas) is 2.088[W] when brightness is set as 75cd. It can vary by the brightness.

Figure 2. Dial of Horn and Strobe

2.1.3 Voltage Drop Calculation for Horn and Strobe

When Horn and Strobe brightness is set as 75cd. Maximum current is 87[mA]. Cable resistance is 0.021[Ω/m]. Cable length from FACP battery to Horn and Strobe is 8m. Calculation is as below.



$$r_1 = r_2 = 0.021(\Omega/\text{m})\text{x}8[\text{m}] = 0.168[\Omega]$$

$$V_{Drop} = i_s(r_1 + r_2) = 87[\text{mA}]\text{x}0.336[\Omega] = 0.02923[\text{V}]$$

Figure 3. Voltage Drop Calculation

Nominal Voltage of FACP battery is 24[V]. A conservative estimate applies 20.4[V], which is 85% of the nominal voltage. Voltage drop is 0.03[V]. Voltage on Horn and Strobe is 20.37[V] which is between operating range from 16[V] ~ 33[V].

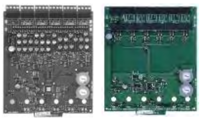
Appearance	Section	Item	Product Information					Certificate Information		
			Manufacturer	Model	Q'ty	Unit	UL Code	UL Category	File No	CSFM
	Fire Alarm Control Panel	FACP	Notifier	NFS-320	1	ea	UL 864	UOJZ	S635	7165-0028:0243
		Network Card	Notifier	HS-NCM-SF	1	ea	UL 864	SYZV	S635	7300-0028:0257
		Lead-Acid Battery	SEBANG	ES30-12	2	ea	UL 1989	BAZR2	MH15934	
	Smoke Detector	Smoke Detector	Notifier	FSP-951	1	ea	UL 268	UROX	S1115	7272-0028:0503
		Base	Notifier	B501-WHITE	1	ea	UL 268	UROX	S1115	7300-1653:0109
	Module	6 Relay Output Module	Notifier	XP6-R	1	ea	UL 864	UOXX	S635	7300-0028:0219
		10 Input Module	Notifier	XP10-M	1	ea	UL 864	UOXX	S635	7300-0028:0219
	Horn and Strobe (Smoke)	Horn and Strobe	Notifier	P2GRKLED	1	ea	UL 464	ULSZ UVAV	S4011	7135-1653:0534
	Horn and Strobe (Gas)	Horn and Strobe	Notifier	P2GWKLED-P	1	ea	UL 464	ULSZ UVAV	S4011	7135-1653:0534
		Amber Lens	Notifier	LENS-A3	1	ea	UL 1638	UVAV	S5512	
	FACP Aux Flexible Conduit Assy	DC Aux Flexible Conduit			16	M	UL listed		E305578	
		FACP SLC Cable	KWAMGIL		6	ea	UL1424	FPL	E472701	
		18 AWG Copper Cable Lug		A-SC1.5-4	6	ea				

Table 4. E-Panel Fire Safety Components

2.2 M-LINK Fire Safety Components

The table below lists the fire safety materials installed in each M-LINK.

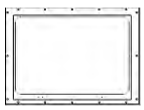
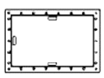
Appearance	Section	Item	Product Information				Certificate Information			
			Manufacturer	Model	Q'ty	Unit	UL Code	UL Category	File No	CSFM
	Smoke Detector	Smoke Detector	Notifier	FSP-951	1	ea	UL 268	UROX	S1115	7272-0028:0503
		Base	Notifier	B501-WHITE	1	ea	UL 268	UROX	S1115	7300-1653:0109
	Module	6 Relay Output Module	Notifier	XP6-R	1	ea	UL 864	UOXX	S635	7300-0028:0219
		2 Input Module	Notifier	FDM-1	1	ea	UL 864	UOXX	S635	7300-0028:0219
	Gas Detector	Gas Detector	Honeywell	XCL	1	ea	UL 61010-1	NYOK	E486160	5278-2383:0001
	Ventilation	Roof Exhaust Vent	INTOR KHAN	-	2	ea				
		Linear Actuator	Timotion	MA2-K	2	ea	UL962	IYOX2	E343440	
		Intake Damper (with Fan)	Electroman	EF17-850-00210	2	ea	UL507	GPWV2	E89520	
	Partial Deflagration Panel	Partial Deflagration Panel	INTOR KHAN		2	ea				
	FACP Aux Flexible Conduit Assy	DC Aux Flexible Conduit			16	M	UL listed		E305578	
		FACP SLC Cable	KWAMGIL		6	ea	UL1424	FPL	E472701	
		Cable Lug								

Table 5. M-LINK Fire Safety Components

3. Fire Safety Logic

3.1 Fire Safety Logic

The E-Panel is configured with Fire Safety Logic through the FACP (Fire Alarm Control Panel), while the M-LINK manages the fire safety system using two methods: the FACP and a PLC (Programmable Logic Controller).

E-Panel

One smoke detector is installed in the E-Panel. When the smoke detector is activated, an alarm is triggered, and the information is shared with the PLC. Also, when it is activated, the fire horn/strobe is triggered, and simultaneously, the HVAC system installed inside the E-panel shuts down.

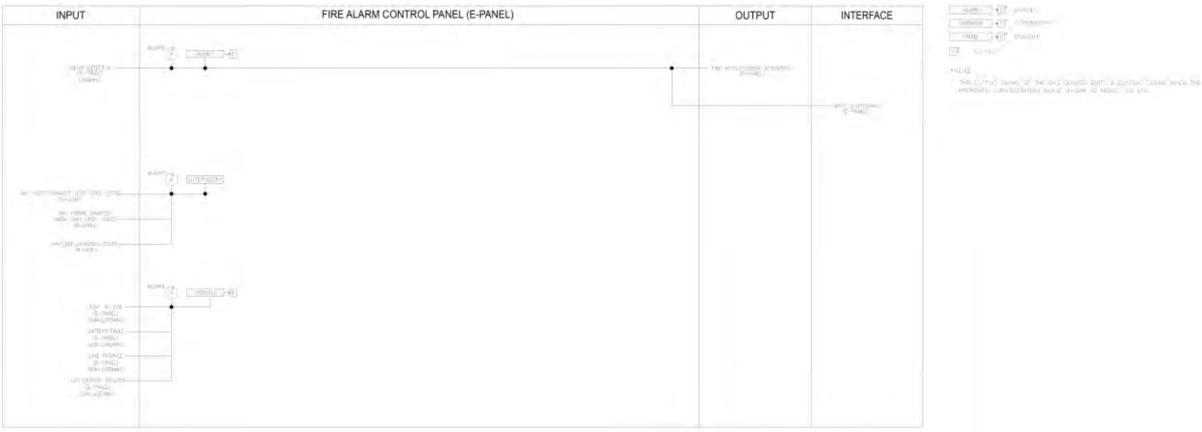


Figure 4. Fire Safety Logic (E-Panel)

(1) M-LINK

One smoke detector and one gas detector are installed in each M-LINK. When smoke detection is activated, the fire horn/strobe is triggered, and simultaneously, the HVAC system inside the M-LINK shuts down, and the ventilation system is activated. Gas detectors are set to detect combustible gas at 10% of the LFL (Lower Flammable Limit) in accordance with NFPA 69. (Detection condition can be set via S/W manner, it will be set before installing on site) When some combustible gas is detected, the ventilation system is activated, which ensures that the gas concentration inside each M-LINK remains below 25% of the LFL. The ventilation system consists of two door intake dampers (with fans), two roof exhaust vents. Even if only one door intake damper and one roof exhaust vent (with fan) are operational, the system still complies with NFPA 69 requirements (below 25% of the LFL). If gas detector or smoke detector is activated in any of three M-LINKs, the entire ventilation system of the JF2 DC/AC LINK 5.1 will be activated. As shown in the Figures below, each M-LINK detects fire and gas using two systems: the FACP (Fire Alarm Control Panel) and the PLC (Programmable Logic Controller). The deflagration panel is designed to ensure that the structure of M-LINK can Withstand and not collapse in the event of an explosion of flammable gas that occurs before the gas sensor is activated (LFL10%).

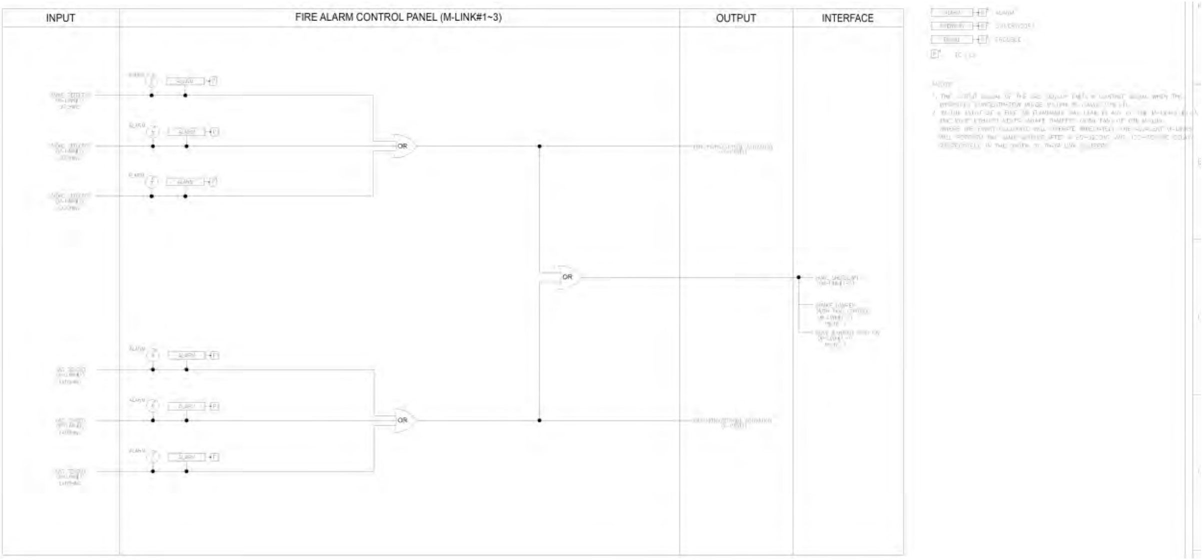


Figure 5. Fire Safety Logic of FACP (M-LINK)

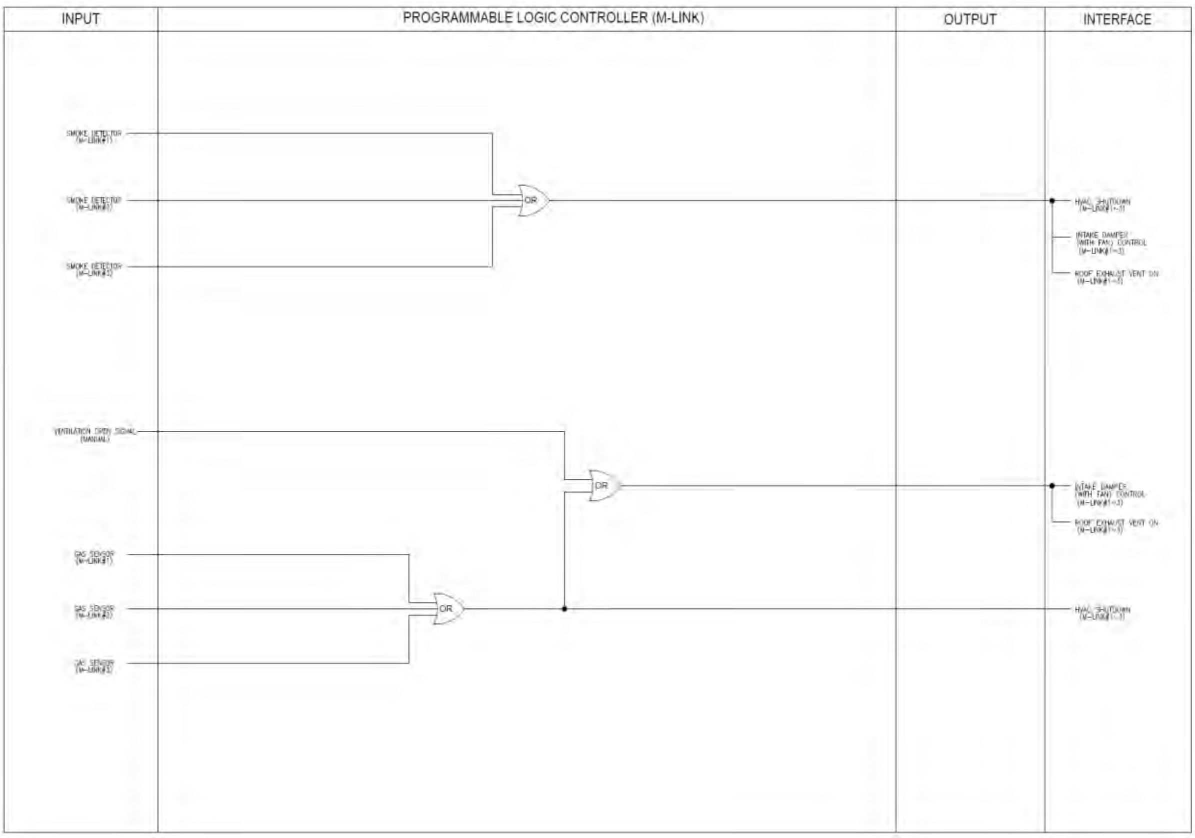


Figure 6. Fire Safety Logic of PLC (M-LINK)

3.2 Cause & Effect Chart

The figure below represents the Cause & Effect Chart of the JF2 DC/AC LINK 5.1. All fire safety information is transmitted to the FCC (Fire Command Center) installed on site.

CAUSE AND EFFECT

ABBREVIATIONS :
X = ACTION / ACTIVATE
X* = 60-SECOND DELAY
X** = 120-SECOND DELAY
NOTES :
1. THE OUTPUT SIGNAL OF THE COMBUSTIBLE GAS DETECTOR EMITS A CONTACT SIGNAL WHEN THE HYDROGEN CONCENTRATION INSIDE M-LINK IS ABOVE 10% LFL.

				EFFECTS	FIRE CONTROL PANEL				E-PANEL								M-LINK-1			M-LINK-2			M-LINK-3		
				DESCRIPTION	DISPLAY ON LCD	ALARM LED / BUZZER	SUPERVISORY LED / BUZZER	TROUBLE LED / BUZZER	FIRE HORN/STROBE ACTIVATION	GAS SENSOR HORN/STROBE	FACP SYSTEM TROUBLE	SMOKE DETECTOR ALARM	HVAC SHUTDOWN	M-LINK#1 SMOKE DETECTOR ALARM	M-LINK#2 SMOKE DETECTOR ALARM	M-LINK#3 SMOKE DETECTOR ALARM	INTAKE DAMPER (WITH FAN) OPEN AND FAN CONTROL	ROOF EXHAUST VENT OPEN CONTROL	HVAC SHUTDOWN	INTAKE DAMPER (WITH FAN) OPEN AND FAN CONTROL	ROOF EXHAUST VENT OPEN CONTROL	HVAC SHUTDOWN	INTAKE DAMPER (WITH FAN) OPEN AND FAN CONTROL	ROOF EXHAUST VENT OPEN CONTROL	HVAC SHUTDOWN
				ADD. NO.	-	-	-	-	TB9-NAC#1	TB8-NAC#2	M100	M101	M102	M103	M104	M105	M25	M26	M28	M45	M46	M48	M65	M66	M68
CAUSE				NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
NO.	ITEM	ADD. NO.	ACTION STATUS																						
	E-PANEL																								
1	SMOKE DETECTOR	D100	ALARM		X	X			X			X	X												
2	INTAKE DAMPER (WITH FAN) OPEN STATE (M-LINK#1)	M120	SUPER.		X		X																		
3	INTAKE DAMPER (WITH FAN) OPEN STATE (M-LINK#2)	M121	SUPER.		X		X																		
4	INTAKE DAMPER (WITH FAN) OPEN STATE (M-LINK#3)	M122	SUPER.		X		X																		
5	ROOF EXHAUST VENT OPEN STATE (M-LINK#1)	M123	SUPER.		X		X																		
6	ROOF EXHAUST VENT OPEN STATE (M-LINK#2)	M124	SUPER.		X		X																		
7	ROOF EXHAUST VENT OPEN STATE (M-LINK#3)	M125	SUPER.		X		X																		
8	FACP AC FAIL		TROUBLE		X			X			X														
9	BATTERY FAULT		TROUBLE		X			X			X														
10	LINE TROUBLE		TROUBLE		X			X			X														
	M-LINK-1																								
1	SMOKE DETECTOR	D10	ALARM		X	X			X					X			X	X	X	X*	X*	X	X**	X**	X
2	GAS SENSOR ALARM	M35	ALARM		X	X				X							X	X	X	X*	X*	X	X**	X**	X
3	GAS SENSOR TROUBLE	M35	TROUBLE		X			X																	
4	DEFLAGRATION STATE	M36	SUPER.		X		X																		
	M-LINK-2																								
1	SMOKE DETECTOR	D20	ALARM		X	X			X						X		X*	X*	X	X	X	X	X**	X**	X
2	GAS SENSOR ALARM	M55	ALARM		X	X				X							X*	X*	X	X	X	X	X**	X**	X
3	GAS SENSOR TROUBLE	M55	TROUBLE		X			X																	
4	DEFLAGRATION STATE	M56	SUPER.		X		X																		
	M-LINK-3																								
1	SMOKE DETECTOR	D30	ALARM		X	X			X							X	X*	X*	X	X**	X**	X	X	X	X
2	GAS SENSOR ALARM	M75	ALARM		X	X				X							X*	X*	X	X**	X**	X	X	X	X
3	GAS SENSOR TROUBLE	M75	TROUBLE		X			X																	
4	DEFLAGRATION STATE	M76	SUPER.		X		X																		

Figure 7. Cause & Effect Chart

4. Fire Alarm System Plan

The figure below shows the cable connections for the JF2 DC/AC LINK 5.1 system.

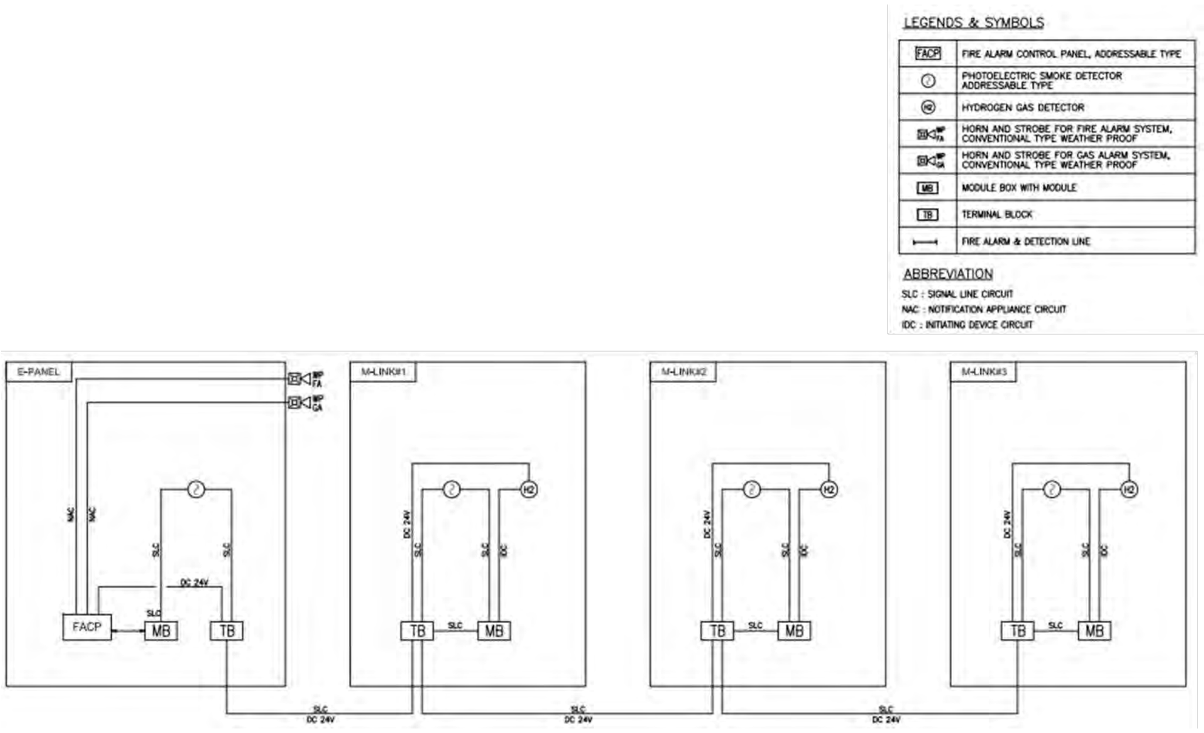


Figure 8. JF2 DC/AC LINK 5.1 Connection Diagram

4.1 System Designer

System Designer name is Hyunmin Lee. And his contact is esshyunmin@lgensol.com

4.2 Pathway Class

Pathway class designation of Fire Alarm System is Class B

4.3 Pathway Survivability Level

Pathway Survivability Level of Fire Alarm System is level 0. The Fire Alarm System cable is certified UL 1424. This cable has undergone Heat Shock Test(135℃, 1 hour)

4.4 E-Panel

(1) FACP

FACP (Fire Alarm Control Panel) has the capability to connect to a UPS power supply, auxiliary power, FCC communication lines, and internal communication lines. The Figure below shows the wiring connections for the FACP (Fire Alarm Control Panel). LG will add a lockout kit on top of the existing MCB for FACP to comply with NFPA 72 clause 10.6.5.2 and 10.6.5.4.

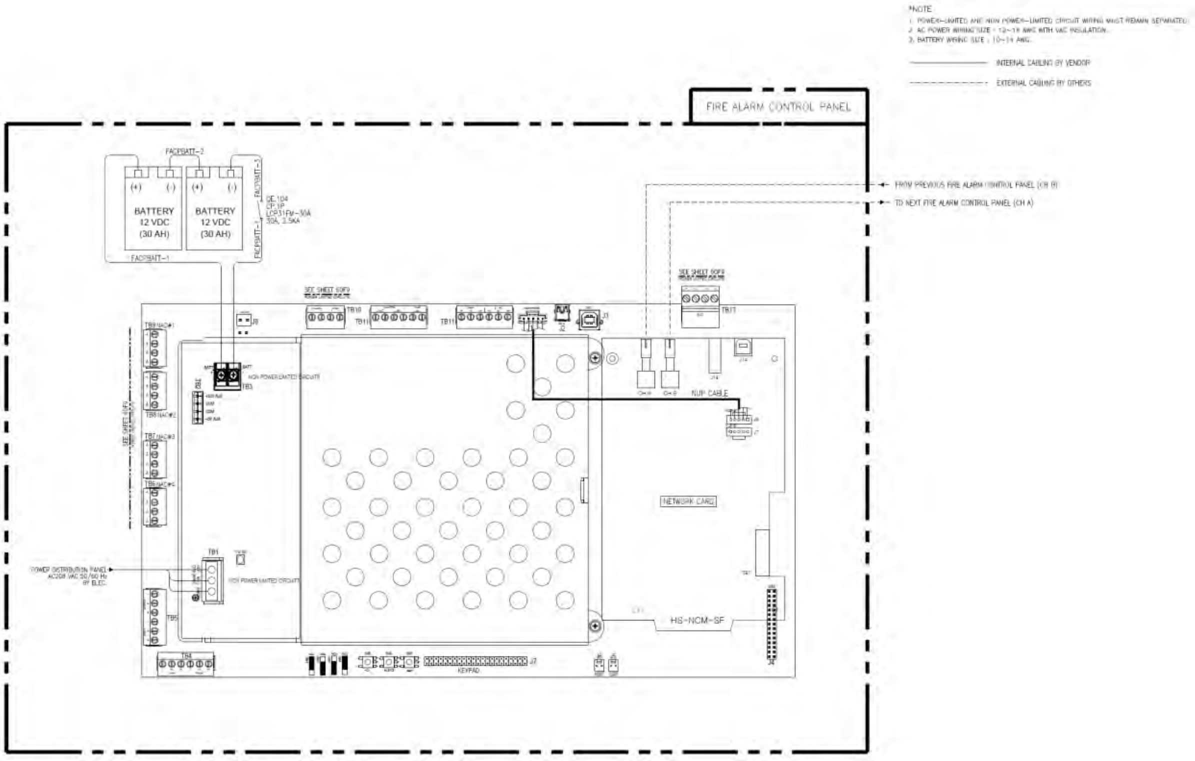


Figure 9. FACP Connection Diagram

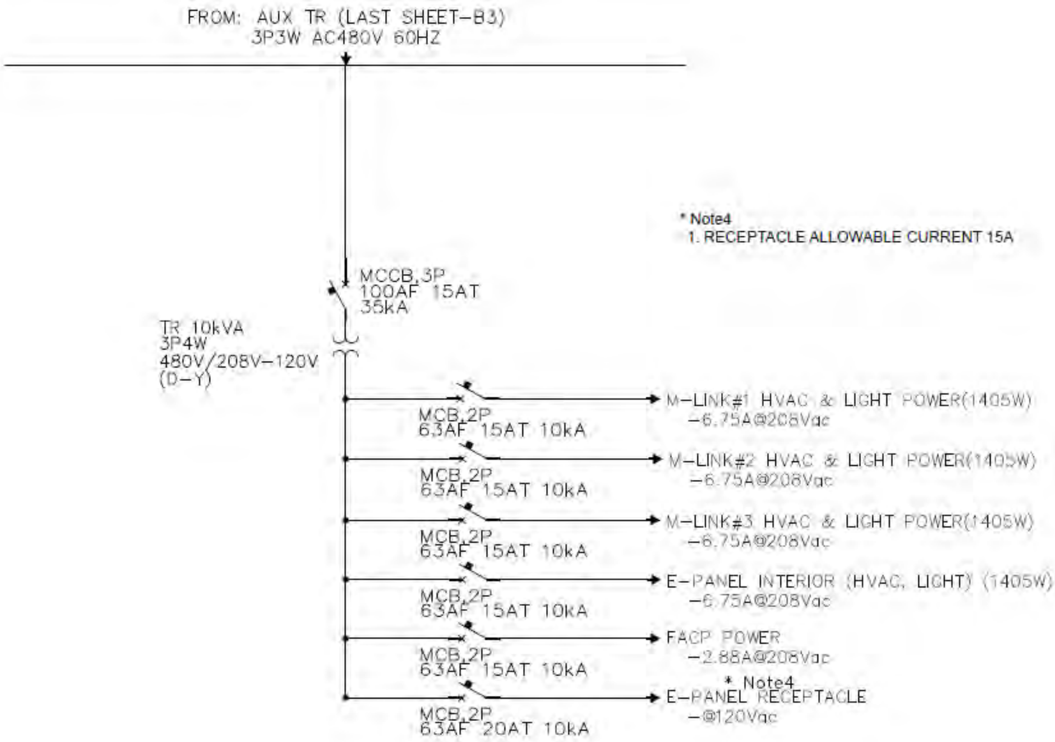


Figure 10. SLD (Breaker for FACP power)

Note: The capacity of each components of SLD may vary depending on the model.

(2) Fire Safety-related Connection in E-Panel

The figure below shows the cable connections for the fire system inside the E-Panel. The cables are connected from the E-Panel to M-LINK 1, then to M-LINK 2, and to M-LINK 3, and finally loop back from M-LINK 3 to the E-Panel. (back loop configuration)

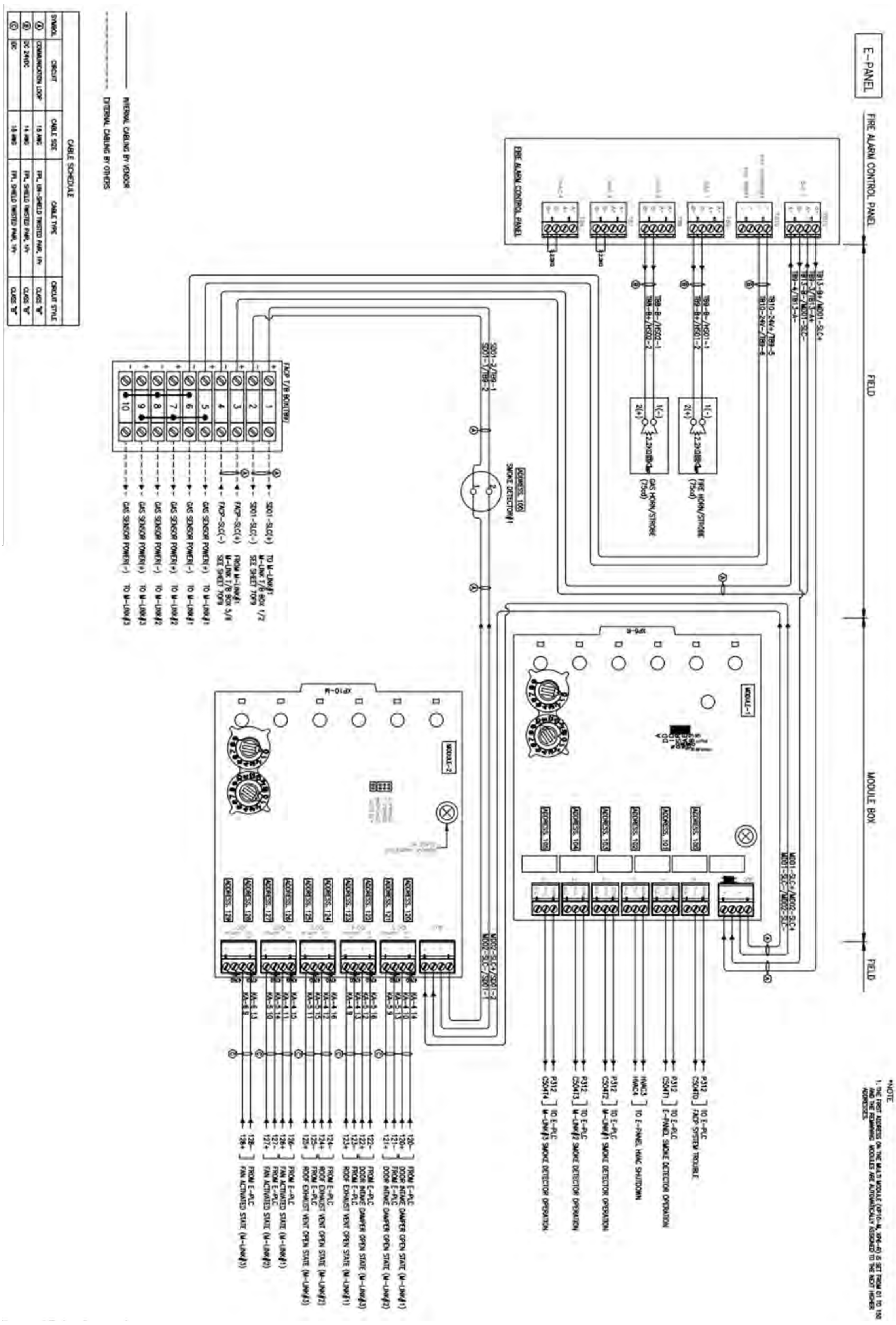


Figure 11. E-Panel Connection Diagram

4.5 M-LINK

The Figure below illustrates the cable connections inside the M-LINK. The smoke detectors are configured on the SLC (Signaling Line Circuit), the horn and strobe are on the NAC (Notification Appliance Circuit), and the gas detectors are on the IDC (Initiating Device Circuit). The fire communication is based on RS-485 communication.

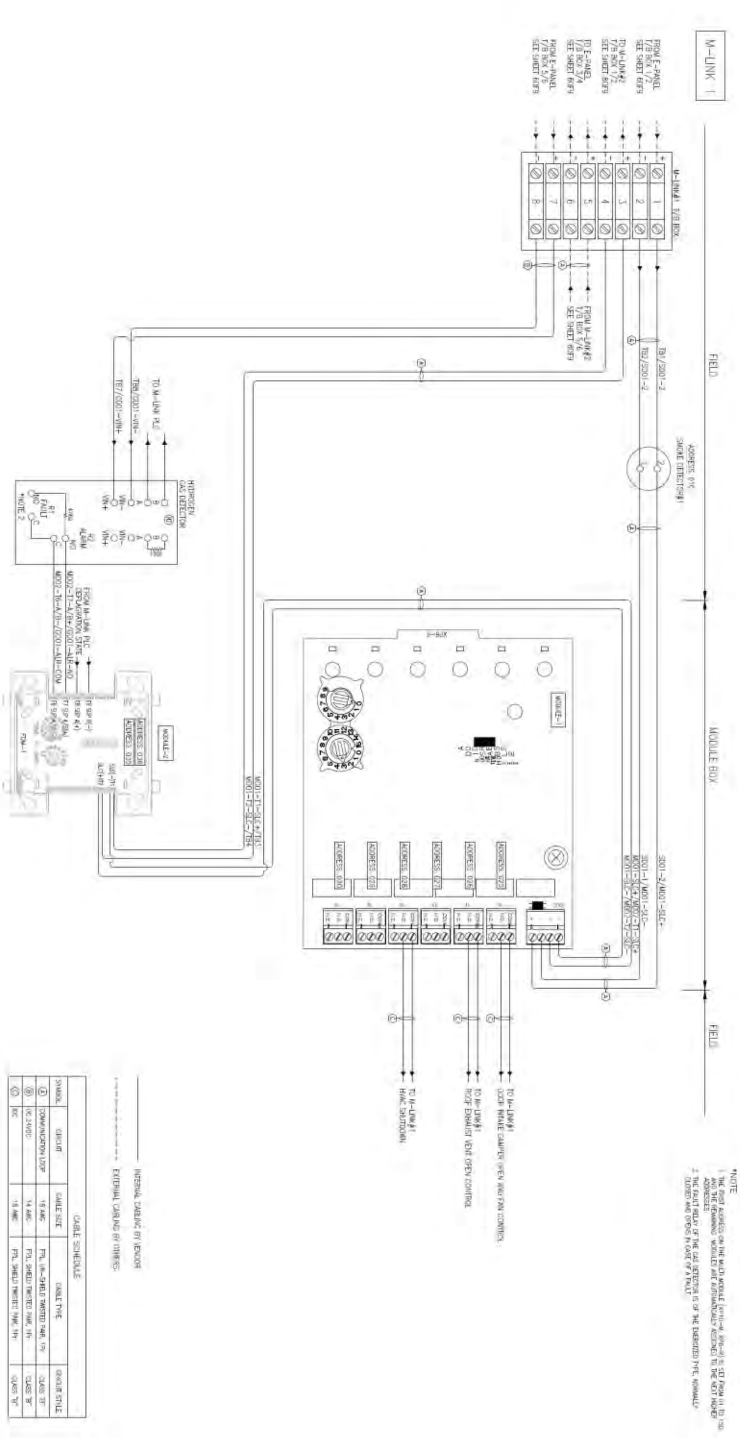


Figure 12. M-LINK 1 Connection Diagram

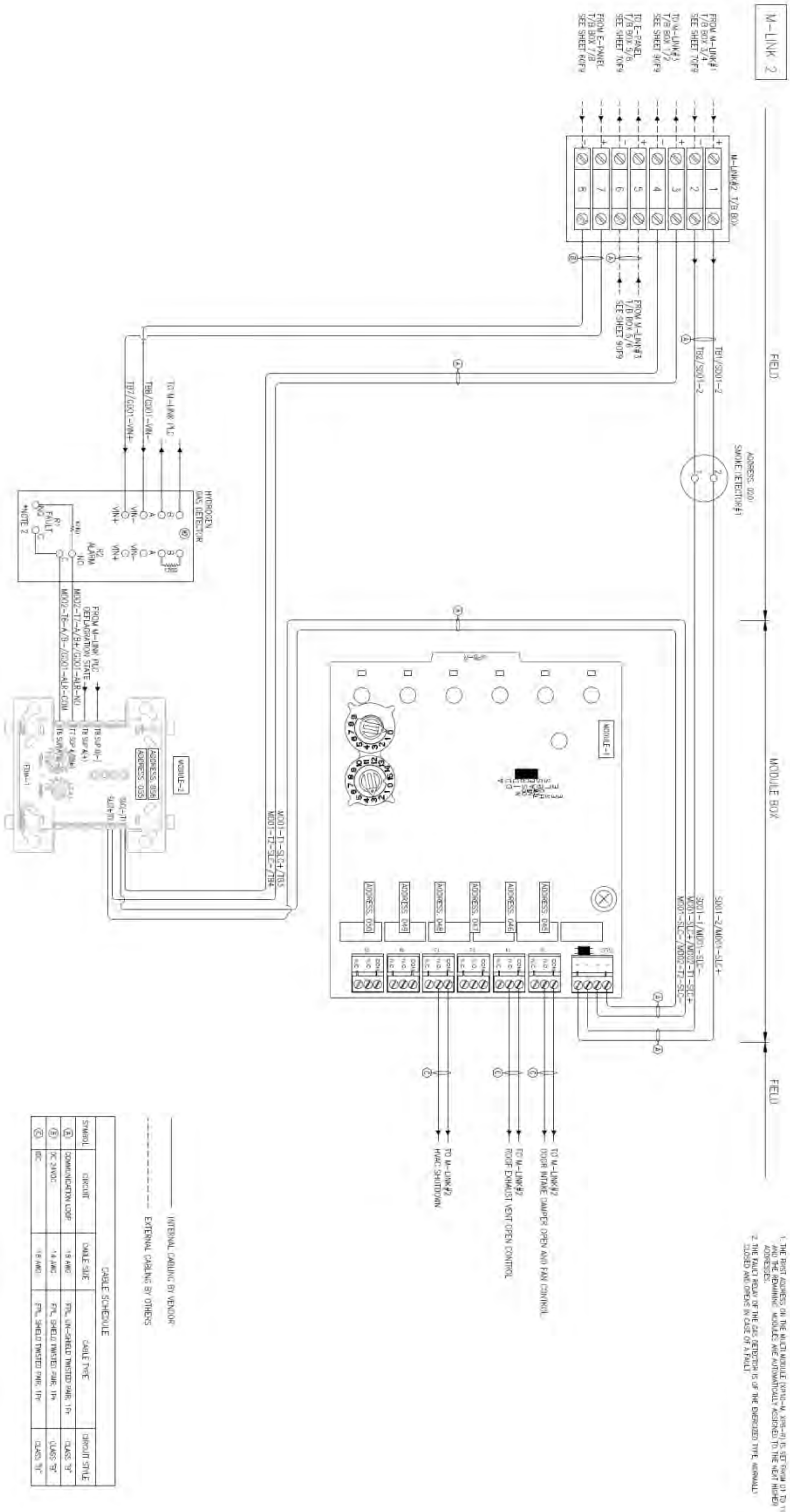


Figure 13. M-LINK 2 Connection Diagram

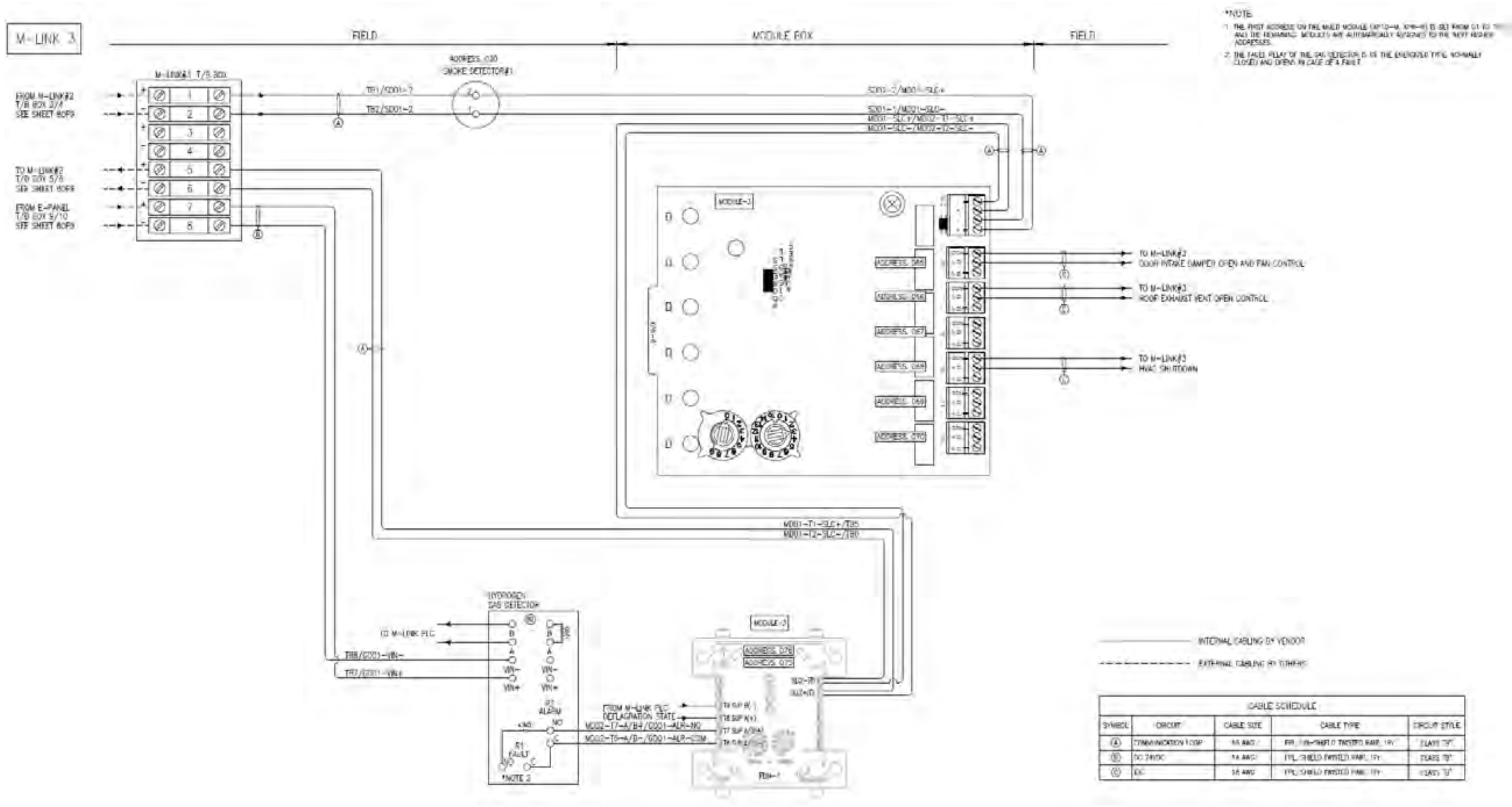
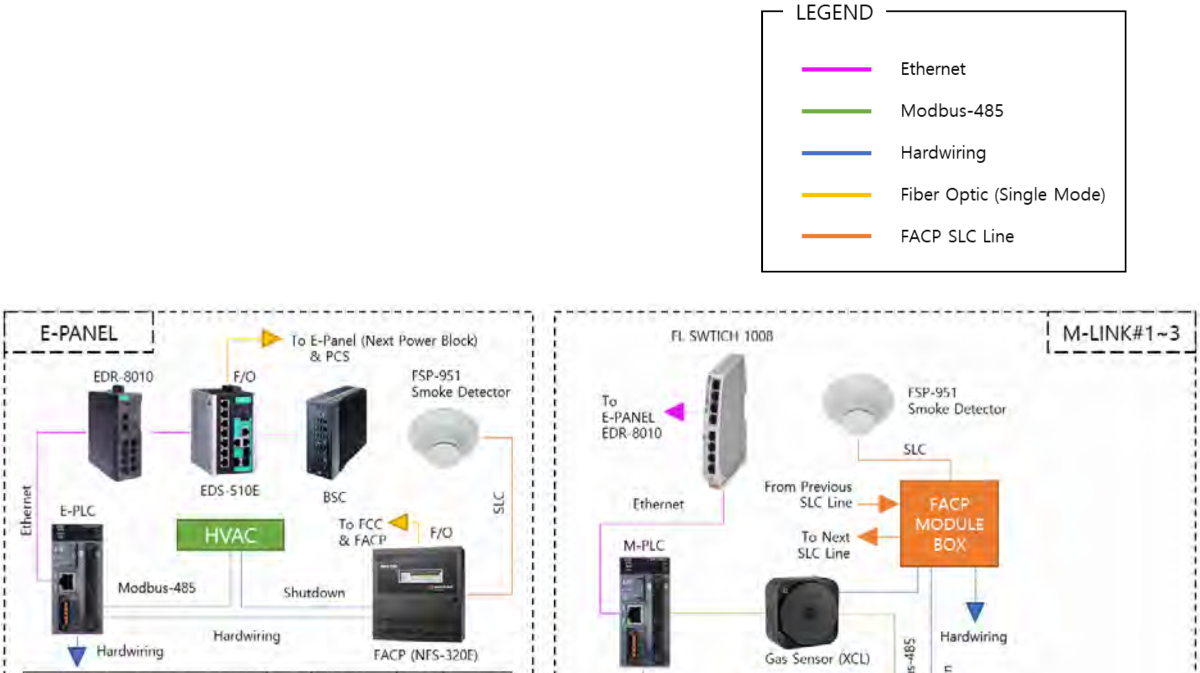


Figure 14. M-LINK 3 Connection Diagram

4.6 Communication

The figure below shows the communication architecture of the JF2 DC/AC LINK 5.1 fire system. The communication between FACP (Fire Alarm Control Panel) and PLC (Programmable Logic Controller) is established through hard-wired signals. The fire system communication via the PLC utilizes RS-485, hard-wired signals, and Modbus TCP.



FACP Hardwiring Signal list	Type	From	To	Point
FACP Trouble	DO	FACP	E-PLC	1
E-PANEL Smoke Detector Alarm	DO	FACP	E-PLC	1
M-LINK Smoke Detector Alarm	DO	FACP	E-PLC	3
E-PANEL HVAC Shutdown	DO	FACP	HVAC	1
Intake Damper State (M-LINK#1~3)	DI	E-PLC	FACP	3
Roof Vent State (M-LINK#1~3)	DI	E-PLC	FACP	3
Intake Fan State (M-LINK#1~3)	DI	E-PLC	FACP	3
E-PLC Hardwiring Signal list	**Type**	**From**	**To**	**Point**
DS State	DI	DS	E-PLC	1
DS Control	DO	E-PLC	DS	2
Fuse State	DI	Fuse	E-PLC	1
Door Limit Switch State	DI	Door S/W	E-PLC	1
DC SPD State	DI	DC SPD	E-PLC	1
AC SPD State	DI	AC SPD	E-PLC	1
Emergency Stop State	DI	E-STOP	E-PLC	1
DC UPS Error	DI	DC UPS	E-PLC	3
SMPS DC OK	DI	SMPS	E-PLC	6
Diesel Generator operation	DI	TB (E Panel)	E-PLC	1
Intake Damper State (M-LINK#1~3)	DO	E-PLC	FACP	3
Roof Vent State (M-LINK#1~3)	DO	E-PLC	FACP	3
Intake Fan State (M-LINK#1~3)	DO	E-PLC	FACP	3
E-PLC Modbus RTU Comm.	**Type**	**From**	**To**	**Point**
E-PANEL HVAC Shutdown	Com	E-PLC	HVAC	1

FACP Hardwiring Signal list	Type	From	To	Point
Gas Sensor Alarm/Trouble	DI	Gas Sensor	FACP	1
Deflagration State	DI	M-PLC	FACP	1
M-LINK HVAC Shutdown	DO	FACP	HVAC	1
Intake Damper with Fan Control (Open)	DO	FACP	Intake Damper with Fan	1
Roof Vent Control (Open)	DO	FACP	Roof Vent	1
M-PLC Hardwiring Signal list	**Type**	**From**	**To**	**Point**
Door Limit Switch State	DI	Door S/W	M-PLC	1
Intake Damper State	DI	Intake Damper	M-PLC	2
Intake Damper with Fan Control (Manual)	DO	M-PLC	Intake Damper with Fan	1
Roof Vent State	DI	Roof Vent	M-PLC	4
Roof Vent Control (Manual)	DO	M-PLC	Roof Vent	2
Intake Fan State	DI	Intake Fan	M-PLC	2
Intake Fan Fault	DI	Intake Fan	M-PLC	2
Deflagration State	DI	Deflag PNL	M-PLC	2
Deflagration State signal to FACP	DO	M-PLC	FACP	1
M-PLC Modbus RTU Comm.	**Type**	**From**	**To**	**Point**
M-LINK HVAC Shutdown	Com	M-PLC	HVAC	1
Gas Sensor State	Com	M-PLC	Gas Sensor	2

Figure 15. JF2 DC/AC LINK 5.1 Fire Safety Architecture (Communication)

5. Location of Components

Symbols are from NFPA170.

	Gas Detector
	Smoke Detector
FACP	Fire Alarm Control Panel
	Horn & Strobe

Figure 16. Symbols of Fire Alarm System Components

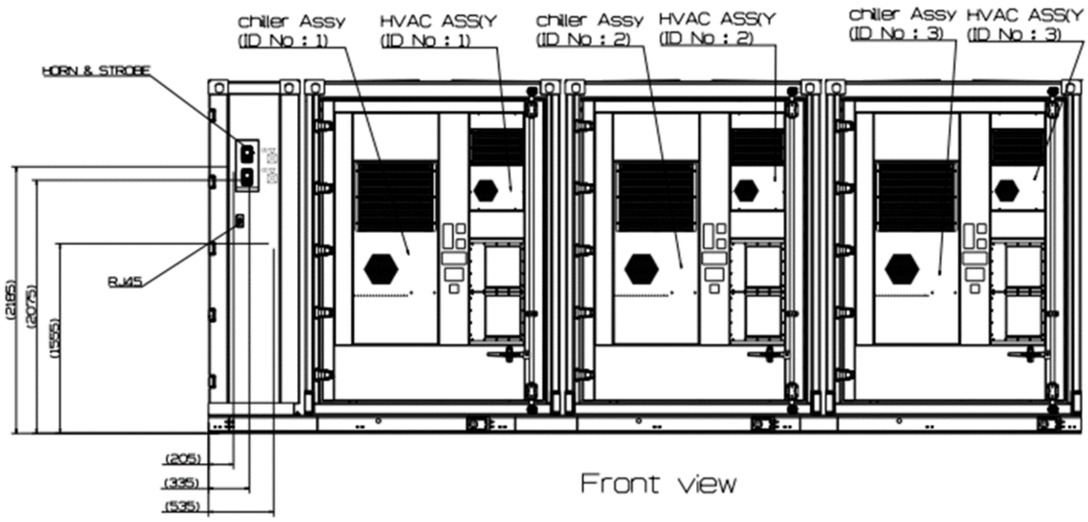


Figure 17. Front View of JF2 DC/AC LINK

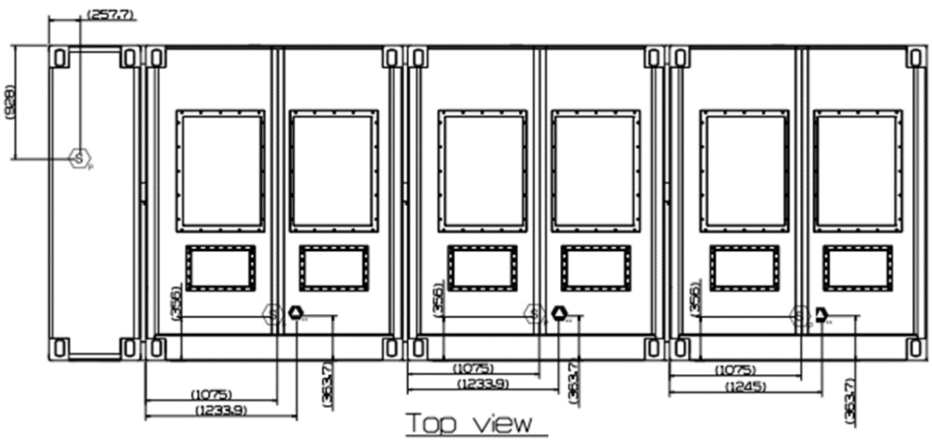


Figure 18. Top View of JF2 DC/AC LINK

5.1 Smoke Sensor (E-Panel)

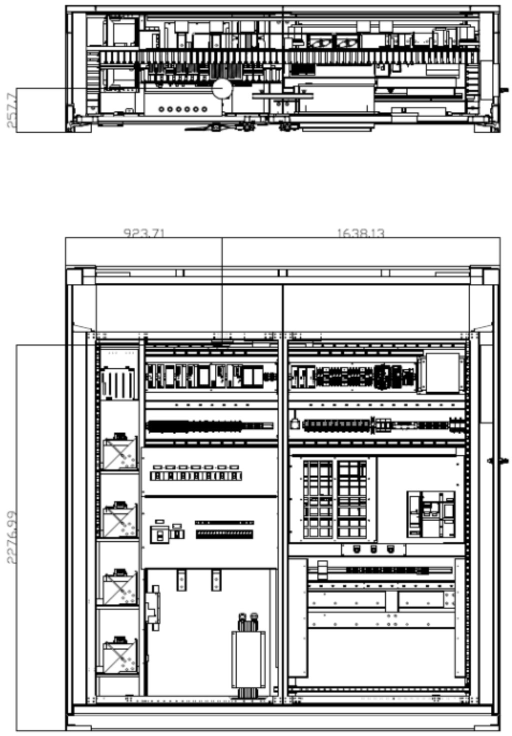


Figure 19. Location of Smoke Sensor (E-Panel)

5.2 Smoke sensor and Gas Detector (M-LINK)

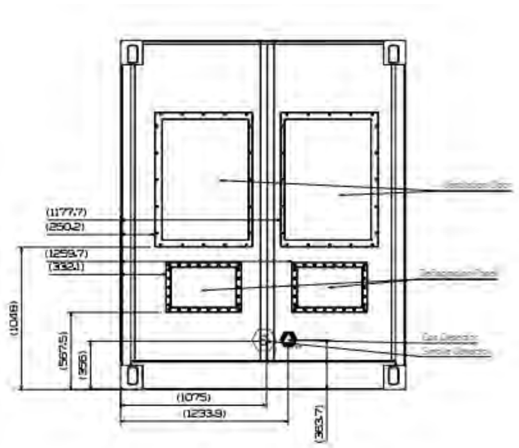


Figure 20. Location of Smoke Detector and Gas Detector (M-LINK, Top view)

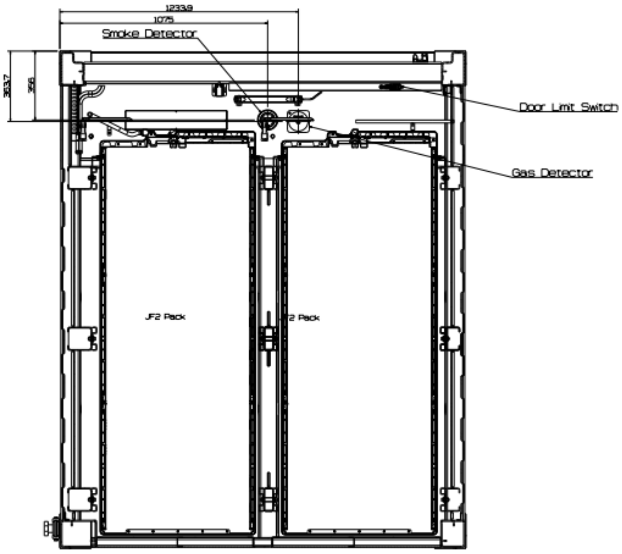


Figure 21. Location of Smoke Detector and Gas Detector (M-LINK, Front view)

5.3 Horn & Strobe (E-Panel)

The exact location can vary from site to site, but it always has the same height based on the ground as below.

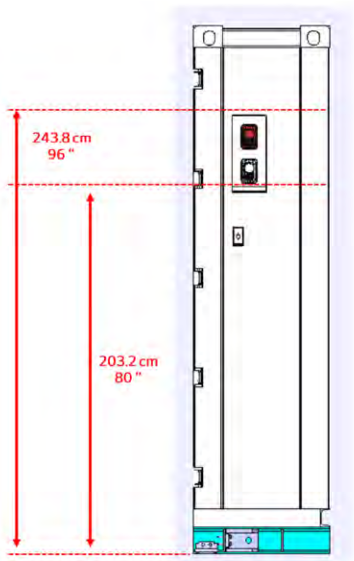


Figure 22. Location of Horn & Strobe (E-Panel)

5.4 FACP (E-Panel)

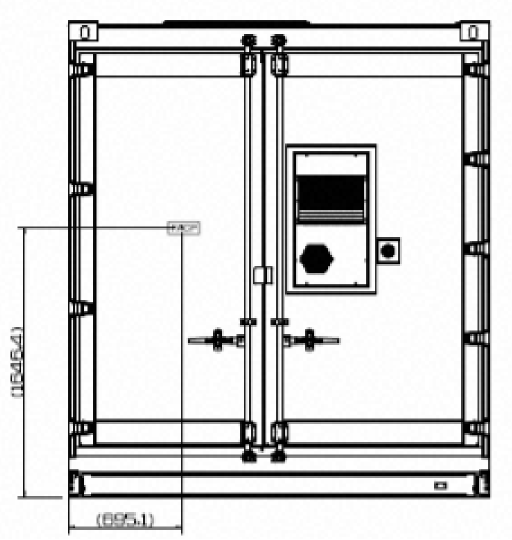


Figure 23. Location of FACP (E-Panel)

6. Power Supply of Fire Alarm System

6.1 FACP Lead-Acid Battery

The FACP (Fire Alarm Control Panel) uses its own batteries and it is designed to back up the loads for 24 hours ‘Standby’ and 2 hours ‘Alarm’ to meet requirement. The main loads are the FACP, smoke detectors, and Horn & Strobe.

Load	Power consumption	Back up time
FACP (Fire alarm control panel, Smoke detectors, Gas sensors, Horn & Strobe)	18[W] (for Standby) 34.8[W] (for Operation)	24 hours for standby power 2 hours for operation

Table 6. Power Load of FACP Lead-Acid Battery

Detail load lists by FACP battery and device current draw below.

NOTIFIER by Honeywell

Device Current Draw

NFS-320 Fire Alarm Control Panel

Quantity x [device current draw] = total current draw per device (in amps)

Part Number	Qty	Primary Non-Alarm	Primary Alarm	Secondary Non-Alarm
CPU-320	1	x [0.25000] = 0.25000	x [0.25000] = 0.25000	x [0.25000] = 0.25000
CPS-24	1	x [0.00000] = 0.00000	x [0.00000] = 0.00000	x [0.04000] = 0.04000
HS-NCM-W/WF/SF/WMF/WSF/WFS	1	x [0.40000] = 0.40000	x [0.40000] = 0.40000	x [0.40000] = 0.40000
FSP-951	4	x [0.00020] = 0.00080	x [0.00000] = 0.00000	x [0.00020] = 0.00080
XP10-M	1	x [0.00350] = 0.00350	x [0.00000] = 0.00000	x [0.00350] = 0.00350
XP6-R	4	x [0.00145] = 0.00580	x [0.00000] = 0.00000	x [0.00145] = 0.00580
FDM-1	3	x [0.00075] = 0.00225	x [0.00000] = 0.00000	x [0.00075] = 0.00225
SLC Loop Device Activation Current	1	x [0.00000] = 0.00000	x [0.40000] = 0.40000	x [0.00000] = 0.00000
P2GRKLED75	2	x [0.00000] = 0.00000	x [0.08700] = 0.17400	x [0.00000] = 0.00000
Gas Sensor	3	x [0.03000] = 0.09000	x [0.07500] = 0.22500	x [0.03000] = 0.09000
Total (Amperes):		**0.7524 A**	**1.4490 A**	**0.7924 A**

Part Number	Qty	Secondary Alarm
Total Primary Alarm Load - C2	1	x [1.44900] = 1.44900
CPS-24	1	x [0.04000] = 0.04000
Total (Amperes):		**1.4890 A**

Figure 24. Device Current Draw of FACP

Below presents the FACP battery calculation for achieving a target standby time of 24 hours and alarming time of 2 hours. Primary Loads are the FACP battery's load when AC power is supplied properly to the Fire Alarm Safety Components. Secondary Loads are the FACP battery's load to Fire Alarm Safety Components during outage.

NOTIFIER by Honeywell

System Power Requirements

Notifier NFS-320 Fire Alarm Control Panel

Protected Premises: ____ Date: ____
Address: ____
City: ____ State: ____ Zip: ____

Prepared By: ____ Phone: ____
Address: ____ Email: ____
City: ____ State: ____ Zip: ____

AC Branch Current Requirements 2.50 AMPS @ 220/240 VAC
Current required by source to power the fire alarm system.

Primary Standby Load 0.75 Amps
Current load on the primary power supply during **non-alarm** conditions.

Primary Alarm Load 1.45 Amps
Current load on the primary power supply during **alarm** conditions.

Secondary Load Requirements 27.49 Amp Hours
Total Secondary Load from the calculation table below.

Current Draw		Time (hours)	Total (AH)
Secondary Standby Load 0.792 A	x	Required Standby Time 24 hours	19.02
Secondary Alarm Load 1.489 A	x	Required Alarm Time (hours) 2.000 hours	2.98
		Total Secondary Load	21.99
		Derating factor	x 1.25
		Secondary Load Requirements (Amp Hours)	**27.49** AH

FACP(Internal Battery)
24hours stand by
2hours alarm

Battery Selection 30 Amp Hours
Select batteries from the list below.
30 AH CUSTOM BATTERY (12 volt)
☒ Two ☐ Four (two 12VDC sets in parallel)

Battery Selection
30Ah, 24VDC

Figure 25. FACP Battery Calculation

6.2 UPS Battery (in the E-Panel)

The load for UPS is associated with the Gas detection & Ventilation System. The target backup time for UPS is set to a minimum of 26 hours. This satisfies the Gas detection & Ventilation System 24-hour standby time and 2 hours in alarm requirement as required by IFC, CFC, PFC and NFPA 855.

<table>
<tr><th colspan="3">Load</th><th>Power consumption</th><th>Back up time</th></tr>
<tr><td rowspan="10">UPS 3
(960W)</td><td>①</td><td>Relay
(15ea, M-LINK #1-3)</td><td>2.86 W</td><td>26 hours</td></tr>
<tr><td>②</td><td>Roof Exhaust Vent_
Operation
(M-LINK Sequential)</td><td>331.2 W</td><td>1 min per 1 M-Link</td></tr>
<tr><td rowspan="3">③</td><td>Intake Fan 2ea for M-LINK
& Damper_
Standby
(All M-LINK #1-3)</td><td>0.18 W
(Standby)</td><td>24 hours</td></tr>
<tr><td>Intake Fan 2ea for M-LINK
& Damper_
Operation Start*
(M-LINK Sequential)</td><td>330 W
(Operation Start)</td><td>5 sec per 1 M-Link</td></tr>
<tr><td>Intake Fan 2ea for M-LINK
& Damper_
Operation
(All M-LINK #1-3)</td><td>390 W
(Operation)</td><td>2 hours</td></tr>
<tr><td rowspan="2">④</td><td rowspan="2">UPS Module
(1ea, E-Panel)</td><td>4.8 W
(Standby)</td><td>26 hours</td></tr>
<tr><td>25 W
(Operation)</td><td>2 hours</td></tr>
<tr><td colspan="2" rowspan="3">Sum</td><td>7.84 W
(Standby)</td><td>24 hours</td></tr>
<tr><td>689.06 W
(Operation Start)</td><td>3 min</td></tr>
<tr><td>417.86 W
(Operation)</td><td>2 hours</td></tr>
</table>

Figure 26. Power load of UPS Battery

7. Operation & Maintenance

7.1 Operation Procedure

(1) Automatic Operation

A fire safety system is operated automatically by means of a detection and control system. If any smoke detector installed in JF2 DC/AC LINK 5.1 is activated, a Fire Alarm signal is sent to the FCC, and the HVAC at the corresponding location is shut down. If a smoke detector or a gas detector installed in M-LINK is activated, all ventilation systems in JF2 DC/AC LINK 5.1 are activated. For detailed operating logic by items, please refer to the "Fire Safety Logic with Cause & Effect Chart" in clause 3.2.

⚠ WARNING

Everyone must evacuate the hazard area promptly upon hearing the pre-discharge alarm. Make sure no one enters the hazard area. Call the fire department immediately.

7.2 Maintenance

This chapter contains maintenance instructions for the Fire Alarm System.

These procedures must be performed regularly in accordance with regulations. If problems arise, a corrective action must be taken.

Take note of the following precautions:

1) This Fire Alarm System must be serviced by qualified personnel only. Qualified personnel mean personnel who have met State approved or recognized certification, licensing, registration, or other comparable requirements that apply to the areas in which the individuals are conducting evaluations or assessments or providing early intervention services.
2) Any environmental or operating condition which causes shorting or grounding of system components can cause system malfunctions.
3) Before servicing any component, disarm the protection system by removing all AC and DC power from the control unit.

(1) Periodic Maintenance Schedule

A regular program of systematic maintenance is essential for continuous, proper operation of all Fire Alarm Systems. A periodic maintenance schedule must be followed and an inspection log maintained for ready reference. As a minimum, the log must record:

1) Inspection interval,
2) The inspection procedure performed,

3) Maintenance performed, if any, as a result of inspection, and

4) The name of inspector performing the task.

Schedule	Requirement	Regulation	Persons
Semi - annually	**Visual Inspection** Fire Alarm Control Panel, Smoke Detector, Horn and Strobe	NFPA 72, Table 14.3.1	1
Annually	**Testing** Fire Alarm Control Panel, Smoke Detector, Horn and Strobe, UPS Battery	NFPA 72, Table 14.4.3.2	2

Table 7. Periodic Maintenance Lists

(2) Annually

At least every 12 months, the enclosure shall be thoroughly inspected to determine if penetrations or other changes have occurred that could adversely affect some leakage or change volume of hazard or both.

Revision History

Version	Date	Writer	Change Description
1.0	01/16/2025-	Hyunmin Lee	Initial Release
2.0	01/30/2025	Hwanseok Choi	Update fire safety logic, connection diagram
3.0	05/15/2025	Hyunmin Lee	Update specification of two fan and deflagration panel
4.0	06/17/2025	Yoonsin Kim	Update certifications, CSFM, FACP battery breaker, figure 10, deflagration panel state signal, gas sensor DI name, UPS power consumption and UPS back up time
5.0	07/03/2025	Yoonsin Kim	Update plan for lockout kit on top of the existing MCB for FACP. Update note for figure 10.

End of Document

Appendix 2-C: Fire and Safety Reports for DC LINK Batteries

SDS

- 20250731_F2XX-5.1US-GN11_Pack Product SDS (PSDS)_V2.0
- F2D4-5.1US-TH01_DC LINK Thermal Component Specification_V4.0-Coolant

	SAFETY DATA SHEET	Version: R0001.0000
LG Energy Solution		Date of issue: 2024-07-31
		Revision date: -
	LGEnergy Solution EP096636PFB1 **Lithium-Ion Battery Module**	Change List: see Section 16

1. IDENTIFICATION

A. Product name

- LG Energy Solution EP096636PFB1 Lithium-Ion Battery Module

B. Recommended use and restriction on use

- General use	: Rechargeable Lithium-Ion Battery
- Restriction on use	: Not available

C. Manufacturer / Supplier / Distributor information

○ Manufacturer information

- Company name	: LGEnergySolution (Nanjing) Co., Ltd..
- Address	: NO.17-18 HENGYIROAD, No 26 HENGFEIROAD NANJING ECONOMY & TECHNOLOGY ,DEVELOPMENT ZONE NANJING CITY, JIANGSU PROVINCE, P.R.C
- Telephone number	: 025-8560-3000
- E-mail address	: lidoudou@lgensol.com

○ Supplier/Distributer information

- Company name	: LGEnergySolution (Nanjing) Co., Ltd..
- Address	: NO.17-18 HENGYIROAD, No 26 HENGFEIROAD NANJING ECONOMY & TECHNOLOGY ,DEVELOPMENT ZONE NANJING CITY, JIANGSU PROVINCE, P.R.C
- Telephone number	: 025-8560-3000
- E-mail address	: lidoudou@lgensol.com

Legal Remark

U.S.A

- The Occupational Safety and Health Administration (OSHA) Hazard Communication Standard, 29 CFR Subpart 1910.1200 does not apply to various subcategories including anything defined by OSHA as an "article". The products are defined as "articles", and are exempted from the requirements for Material Safety Data Sheets.

EU

- The products are no “substances” or “mixtures” according to Regulation (EC) No 1907/2006 EC. Instead they have to be regarded as “articles”, no substances are intended to be released during handling. Therefore there is no obligation to supply a Safety Data Sheet according to Regulation (EC) 1907/2006, Article 31.

General remark

- This Safety Data Sheet is provided as a service to our customers. This information is based on our current knowledge and is intended to describe the product for the purposes of health, safety and environmental requirements only.
- It should not therefore be construed as guaranteeing any specific property of the product.

2. HAZARD IDENTIFICATION

A. GHS Classification

- No classification is presented since the product is legally an article rather than chemical substance or mixture according to The Occupational Safety and Health Administration (OSHA) Hazard Communication Standard, 29 CFR Subpart 1910.1200

B. GHS label elements

- Not applicable

C. Other hazards which do not result in classification :

- Not available

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1. LG Energy Solution JF2 Lithium-Ion Battery Cell

Chemical Name	CAS No.	Content(%)
Carbon	7440-44-0	22.1
Aluminium	7429-90-5	9.2
Copper	7440-50-8	6.9
Ethyl methyl carbonate	623-53-0	18.1
1,1-Difluiroethene homopolymer	24937-79-9	1.3
Lithium Iron Phospahate Co-Crystallized	15365-14-7	42.4

3.2 LG Energy Solution EP096636PFB1 Module

Chemical Name	Trade names and Synonyms	CAS No.	Content(%)
3.1. LG Energy Solution JF2 Lithium-Ion Battery Cell	Shown as on Table 3.1		78
Aluminium		7429-90-5	10
Iron		7439-89-6	6
Carbonic dichloride polymer with 4,4'-(1-methylethylidene) bis[phenol], 4-(1,1-dimethylethyl)phenylester		103598-77-2	2
1-Propene polymer with ethene		9010-79-1 / KE-29433	2
2,6-Dimethylphenol homopolymer		25134-01-4 / KE-11767	1
Copper		7440-50-8	1

4. FIRST AID MEASURES

A. Eye contact

- Not a health hazard.

B. Skin contact

- Not a health hazard.

C. Inhalation contact

- Not a health hazard.

D. Ingestion contact

- Get medical attention immediately.

<u>IF EXPOSURE TO INTERNAL MATERIALS WITHIN CELL DUE TO DAMAGED OUTER CASING, THE FOLLOWING ACTIONS ARE RECOMMENDED ;</u>

- Obtain special instructions before use.
- Do not handle until all safety precautions have been read and understood.
- Keep away from heat/sparks/open flames/hot surfaces.
- Keep/Store away from clothing /combustible materials.
- Do not breathe dust/fume/gas/mist/vapours/spray.
- Do not get in eyes, on skin, or on clothing.
- Avoid release to the environment.
- Wear protective gloves/protective clothing/eye protection/face protection.
- Use personal protective equipment as required.

A. Eye contact

- Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
- Get medical attention immediately.

B. Skin contact

- Wash with plenty of soap and water.
- Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
- Take off contaminated clothing and wash it before reuse.
- Get medical attention immediately.
- If skin irritation or rash occurs, Get medical advice/attention.
- Wear gloves when washing the patient, and please avoid contact with contaminated clothing.

C. Inhalation contact

- Remove victim to fresh air and keep at rest in a position comfortable for breathing.
- Take specific treatment if needed.
- Get immediate medical advice/attention.
- If breathing is stopped or irregular, give artificial respiration and supply oxygen.

D. Ingestion contact

- Rinse mouth.
- Immediately call a POISON CENTER or doctor/physician.
- Get immediate medical advice/attention.
- About whether I should induce vomiting Take the advice of a doctor.

E. Delayed and immediate effects and also chronic effects from short and long term exposure

- Not available

F. Notes to physician

- Notify medical personnel of contaminated situations and have them take appropriate protective measures.

5. FIREFIGHTING MEASURES

A. Suitable (Unsuitable) extinguishing media

- Use extinguishing media suitable for the materials that are burning.

B. Specific hazards arising from the chemical

- Cell is not flammable but internal organic material will burn if the cell is incinerated. Combustion products include, but are not limited to hydrogen fluoride, carbon monoxide and carbon dioxide.

C. Special protective actions for firefighters

- Notify your local firestation and inform the location of the fire and characteristics hazard.
- Avoid inhalation of materials or combustion by-products.
- Use appropriate extinguishing measure suitable for surrounding fire.
- Wear appropriate protective equipment.
- Use fire fighting procedures suitable for surrounding area.
- If possible, remove cell(s) from fire fighting area. If heated above 150° C, cell(s) may combust/vent.
- Use NIOSH/MSHA approved full-face self-contained breathing apparatus (SCBA) with full protective gear.

6. ACCIDENTAL RELEASE MEASURES

A. Personal precautions, protective equipment and emergency procedures

- Protective equipment: Wear proper protective equipment
- Emergency procedures:

  On Land
  Place material into suitable containers and call local fire/police department.
  In Water
  If possible, remove from water and call local fire/police department.

- If required, notify relevant authorities according to all applicable regulations.

B. Environmental precautions

- Prevent runoff and contact with waterways, drains or sewers.
- Advise emergency services.

C. Methods and materials for containment and cleaning up

- Control personal contact by using protective equipment.
- Prevent, by any means available, containment from entering drains or water course.
- Dispose of waste in accordance with local regulation.

7. HANDLING AND STORAGE

A. Precautions for safe handling

- No special protective clothing required for handling individual cells.
- Do not expose battery or cell to extreme temperatures or fire.
- Do not disassemble, crush or puncture battery.
- Do not overcharge or over discharge the battery.
- Do not connect (short circuit) positive and negative terminals.
- Do not place the batteries on conductive metal.

B. Conditions for safe storage, including any incompatibilities

- Store in a cool, dry place.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

A. Exposure limits

○ **ACGIH TLV**

- Not available

○ **OSHA PEL**

- Not available

B. Engineering controls

- Keep away from heat and open flame.
- Store in cool and dry place.

C. Personal protective equipment

○ **Respiratory protection**

- Not required during normal operations.
- SCBA required in the event of fire.

○ **Eye protection**

- Not required beyond safety practices of employer.

○ **Hand protection**

- Not required for handling of cells.

○ **Skin protection**

- Steel toed shoes recommended for large container handling.

○ **Others**

- Not available

9. PHYSICAL AND CHEMICAL PROPERTIES

A. Appearance	
- Appearance	Solid
- Color	Not available
B. Odor	Not available
C. Odor threshold	Not available
D. pH	Not available
E. Melting point/Freezing point	Not available
F. Initial Boiling Point/Boiling Ranges	Not available
G. Flash point	Not available
H. Evaporation rate	Not available
I. Flammability(solid, gas)	Not available
J. Upper/Lower Flammability or explosive limits	Not available
K. Vapour pressure	Not available
L. Solubility	Insoluble
M. Vapour density	Not available
N. Specific gravity(Relative density)	Not available
O. Partition coefficient of n-octanol/water	Not available
P. Autoignition temperature	Not available
Q. Decomposition temperature	Not available
R. Viscosity	Not available
S. Molecular weight	Not available

10. STABILITY AND REACTIVITY

A. Chemical Stability

- None during normal operating conditions.

B. Possibility of hazardous reactions

- None during normal operating conditions.

C. Conditions to avoid

- Avoid exposure to heat, open flame, and corrosives.
- Do not puncture, crush or incinerate.

D. Incompatible materials

- None during normal operating conditions.

E. Hazardous decomposition products

- None during normal operating conditions.
- If cells are damaged, hydrogen fluoride and carbon monoxide may be released.

11. TOXICOLOGICAL INFORMATION

A. Information on the likely routes of exposure

○ **(Respiratory tracts)**

- None during normal operating conditions.

○ **(Oral)**

- None during normal operating conditions.

○ **(Eye·Skin)**

- None during normal operating conditions.

B. Delayed and immediate effects and also chronic effects from short and long term exposure

○ **Acute toxicity**

*** Oral**

- This product does not elicit toxicological properties during routine handling and use.

*** Dermal**

- This product does not elicit toxicological properties during routine handling and use.

*** Inhalation**

- This product does not elicit toxicological properties during routine handling and use.

○ **Skin corrosion/irritation**

- No irritation.
- If the cells are opened through misuse or damage, discard immediately. Internal components of cell are irritants and sensitizers.

○ **Serious eye damage/irritation**

- Not available

○ **Respiratory sensitization**

- Not available

○ **Skin sensitization**

- No sensitization.
- If the cells are opened through misuse or damage, discard immediately. Internal components of cell are irritants and sensitizers.

○ **Carcinogenicity**

- Not available

○ **Germ cell mutagenicity**

- Not available

○ **Reproductive toxicity**

- This product does not elicit toxicological properties during routine handling and use.

○ **STOT-single exposure**

- Not available

○ **STOT-repeated exposure**

- Not available

○ **Aspiration hazard**

- Not available

12. ECOLOGICAL INFORMATION

A. Ecotoxicity

○ **Fish**

- Not available

○ **Crustaceans**

- Not available

○ **Algae**

- Not available

B. Persistence and degradability

○ **Persistence**

- Not available

○ **Degradability**

- Not available

C. Bioaccumulative potential

○ **Bioaccumulative potential**

- Some materials within the cell are bioaccumulative. Under normal conditions, these materials are contained and pose no risk to persons or the surrounding environment.

○ **Biodegration**

- Not available

D. Mobility in soil

- Not available

E. Other adverse effects

- Not available

13. DISPOSAL CONSIDERATIONS

A. Disposal methods

- Dispose of according to all federal, state, and local regulations.
  Follow Directive 2006/66/EC.
  California regulated debris
  RCRA Waste Code : Non regulated

B. Special precautions for disposal

- Not available

14. TRANSPORT INFORMATION

A. UN No.

- 3481

B. Proper shipping name

- Lithium Ion Batteries contained in Equipment

C. Hazard Class

- Class 9
- Hazard label: Miscellaneous

D. Packing group

- II

E. Marine pollutant

- Not available

F. Special precautions for user related to transport or transportation measures

IMO

-Packing Instruction: LP903

- Special Provision: 188, 230, 310, 957

- EmS: F-A, S-I

UN DOT

- This product is not subject to any other requirements of dangerous goods under 49
- CFR 173.185 (Lithium Batteries and Cells).

15. REGULATORY INFORMATION

A. National and/or international regulatory information

○ **Information of EU Classification**

- Information according to Regulation (EC) No 1272/2008 [CLP]
- Information according to Directive 67/548/EEC

○ **U.S. Federal regulations**

- Information according to ISHA
- Information according to TCCA and other chemical management regulations
- Dangerous Substances Safety Management Act
- Regulation of Disposal
- OSHA hazard communication standard (29 CFR 1910.1200)

a√_ Hazardous ___ Non-hazardous

16. OTHER INFORMATION

A. Reference

- This information is based on our present state of knowledge. It shall describe our products regarding safety requirements and shall not be construed as a guarantee or statement of condition and/or quality
- Information contained in this safety data sheet is based on LG Energy Solution owned data and public sources deemed valid or acceptable. The absence of data elements indicates, that no data meeting these requirements is available

B. Issue date

- 2024-07-31

C. Revision number and Last date revised

-

D. Other

- This SDS is prepared according to the Globally Harmonized System (GHS).

SEV1-R3A-35电池系统低电导率冷却液
SEV1-R3A-35 Battery system low conductivity coolant

三阳科创

版本：1.3	修订日期：2024-09-25	SDS编号：SY-TD-MSDS-042	发行日期：2021-05-19
version：1.3	Revision Date：2024-09-25	SDS Number：SY-TD-MSDS-042	Issue date：2021-05-19

第1部分 化学品及企业标识
Section 1 Chemicals and corporate identification

产品名称 Product Name	:	电动汽车低电导率冷却液 Low conductivity coolant for electric vehicle
产品代码 Product Code	:	SEV1-R3A-35
供应商/制造商 Supplier/Manufacturer	:	江苏三阳环保科技有限公司 Jiangsu Samyang Environmental Science Technology Co., Ltd.
地址 Address	:	江苏省盐城市经济技术开发区盐渎东路117号No.117 Yandu East Road, Yancheng Economic and Technological Development Zone, Jiangsu Province
电话 Telephone	:	0515-88256551
应急咨询电话 Emergency consultation telephone	:	0515-88256551
电子邮件 E-mail	:	xinxinzheng@samyangind.com
推荐用途 Recommended uses	:	防冻剂、冷却剂 Antifreeze、Coolant

第2部分 危害识别
Section 2 Hazards identification

危险性类别
Classification

急性毒性 (经口) Acute Toxcity--Oral	:	类别 4 Category 4
特异性靶器官系统毒性(反复接触) Specifc target organ toxicity--repeated exposure	:	类别 2 Category 2

标签要素
Label elements

象形图
Hazard Pictograms :

信号词
Signal Word(S) :
警告
Warning

危险性说明
Hazard Statement :
H302 吞咽有害。
H302 Harmful if swallowed.
H373 长期或反复接触可能损害器官。
H373 Prolonged or repeated exposure may cause damage to organs.

防范说明
Precautionary statement :
P260 不要吸入烟雾或蒸气。
P260 Do not breathe dust/fume/gas/mist/vapours/spray.
P264 作业后彻底清洗皮肤。
P264 Wash thoroughly after work.
P270 使用本产品时不要进食、饮水或吸烟。
P270 Do not eat, drink or smoke when using this product.
P301 + P312 如误吞咽：如感觉不适,呼叫急救中心/医生。
P301+P312 IF SWALLOWED:Call a poison center/doctor if you feel unwell.
P330 漱口。
P330 Rinse mouth.
P314 如感觉不适,须求医/就诊。
P314 If you feel unwell, you must seek medical advice.
P501 将内装物/容器送到批准的废物处理厂处理。
P501 Dispose of contents/container in accordance with local regulation.

物理和化学危险
Physical and chemical hazards
根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

健康危害
Health hazard
吞咽有害。长期或反复接触可能损害器官。
Swallowing is harmful. Long-term or repeated contact may damage organs.

环境危害
Environmental harm
根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

GHS 未包括的其他危害
Other hazards not covered by GHS
未见报道。
No report.

第3部分 成分/组成信息
Section 3 Composition/information on ingredients

纯品/混合物 Substance/Mixture : 混合物 Mixture

组分
Component

化学品名称 Chemical Name	化学文摘登记号 CAS No.	浓度或浓度范围 (% w/w) Proportion range (% w/w)
乙二醇 Ethylene glycol	107-21-1	50-55%
EDI去离子水 EDI deionized water	7732-18-5	45-50%
添加剂 Additives	N/A	1-5%

第4部分 急救措施
Section 4 First aid measures

急救措施描述
Description of first aid measures : 如果有任何疑问，或症状持续，请就医。
In all cases of doubt, or when symptoms persist, seek medical attention.

吸入
In case of inhalation : 移到有新鲜空气的地方，保持呼吸道畅通。如果呼吸困难，给病人吸氧，并征求医生意见。
Move to fresh air. If breathing has stopped, give artificial respiration first aid. Seek medical attention.

皮肤接触
In case of skin contact : 脱掉被污染的衣服，用肥皂和水彻底冲洗皮肤。如果发生皮肤炎症或皮疹，请就医。
Take off contaminated clothing.Rinse the skin thoroughly with soap and water.Seek medical attention if skin inflammation or rash occurs.

眼睛接触
In case of eyes contact : 用大量水冲洗眼睛至少 15 分钟，就医。
Flush eyes with plenty of water for at least 15 minutes. Seek medical attention.

食入
In case of ingestion : 如果摄入但有意识地喝水或牛奶并积极寻求医疗帮助，除非得到医疗保健患者的指示，否则不要催吐。如果您无法从医生那里获得帮助，请将患者和容器和标签送到最近的医疗急救中心或医院。不要给失去知觉的病人任何食物。
If ingested, but conscious, water or milk to drink and actively seek medical help, do not induce vomiting unless instructed by healthcare patients. If you cannot get help from a doctor, please send the patient and the container and label to the nearest medical emergency center or hospital. Do not give any food to unconscious patients.

最重要的急性和迟发性症状和影响
Most important symptoms and effects, both acute and delayed : 它会导致眼睛发炎，例如发红和视力模糊。食入和呕吐可能导致化学物质进入肺部，引起肺炎和肺损伤。据悉，过量摄入会导致肝肾损害。接触蒸汽或雾气会导致鼻子、喉咙和肺部发炎。出现头痛、恶心、嗜睡、意识不清和头晕等症状。短期接触皮肤会引起轻微的炎症。长期皮肤接触会引起更严重的炎症和不适，局部红肿。
It can cause inflammation of the eyes, such as redness and blurred vision. Ingestion and vomiting may cause chemicals to enter the lungs, causing pneumonia and lung damage. It is reported that excessive intake can cause liver and kidney damage. Exposure to steam or mist can cause inflammation of the nose, throat, and lungs. Symptoms such as headache, nausea, drowsiness, unconsciousness, and dizziness. Short-term contact with the skin can cause slight inflammation. Long-term skin contact can cause more severe inflammation and discomfort, local redness and swelling.

需要立即就医和特别治疗的迹象 Indication of any immediate medical attention and special treatment needed	中毒的迹象有点类似于一般的醉酒，最初是兴奋，然后是昏迷和抽搐。症状包括手舞足蹈、困倦、呕吐、腹泻、口渴和抽搐。中毒的最后阶段包括因酸中毒引起的肾脏损害。静脉注射酒精可作为乙二醇/二甘醇的解毒剂。及时治疗可减少肾脏损害，必要时进行血液透析。如果吞食后自然发生呕吐，因吸入肺部而出现呼吸困难的患者应监测至 48 小时。 The signs of poisoning are somewhat similar to general drunkenness, with initial excitement followed by coma and convulsions. Symptoms include hand dancing, drowsiness, vomiting, diarrhea, thirst, and convulsions. The final stage of poisoning includes kidney damage due to acidosis. Intravenous alcohol injection can be used as an antidote to ethylene glycol/diethylene glycol. Timely treatment can reduce kidney damage, and hemodialysis if necessary. If vomiting has occurred naturally after ingestion, patients with dyspnea should be monitored until 48 hours due to inhalation of the lungs.

第5部分 消防措施
Section 5 Firefighting measures

灭火剂
Extinguishing media

适用的灭火剂 Suitable extinguishing media	泡沫、洒水或喷雾。化学干粉、二氧化碳、沙子或泥浆只能用于小规模火灾。 Foam,sprinkle water or spray.Dry chemical powder,carbon dioxide,sand or mud should only be used for small-scale fires.
不合适的灭火剂 Unsuitable extinguishing media	水射流和卤化物灭火剂。 Water jet.Halide fire extinguisher.
有害分解产物或副产物 Special hazards arising from the substance or mixture	有害燃烧物品可能包括：空气中固体和液体颗粒和气体（烟雾）的复杂混合物，一氧化碳，无法识别的有机和无机化合物。 Hazardous combustion items may include: A complex mixture of airborne solids and liquid particles and gases (smoke). Carbon monoxide, unrecognized organic and inorganic compounds.
消防建议 Advice for firefighters	如果发生火灾，请佩戴自给式呼吸器。使用个人防护装备，使用个人防护装备，用水喷雾冷却容器/罐。 In the event of fire,wear self-contained breathing apparatus.Use personal protective equipment.Wear chemical resistant oversuit.Cool containers/tanks with water spray.

第6部分 泄漏应急处理
Section 6 Accidental release measures

作业人员防护措施、防护设备和应急程序
Personal precautions, protective equipment and emergency procedures

非紧急工作人员 For non-emergency personnel	在确保安全的前提下，防止进一步泄漏或溢出。远离不安全的产品。 Prevent further leakage or spillage if safe to do so. Keep away from Incompatible products.
紧急救援人员 For emergency responders	将人员疏散到安全区域，让人们远离溢出/泄漏点和上风处，使该区域通风，并穿戴合适的防护服。 Evacuate personnel to safe areas. Keep people away from and upwind of spill/leak. Ventilate the area. Wear suitable protective clothing.
环境保护措施 Environmental Precautions	不应释放到环境中；不要冲入地表水或下水道系统。如果产品污染河流和湖泊或下水道，请通知有关当局。 Should not be released into the environment. Do not flush into surface water or sanitary sewer system. If the product contaminates rivers and lakes or drains inform respective authorities.
遏制和清理的方法和材料 Methods and material for Containment and Cleaning up	使用沙子、泥土或其他可用作屏障的材料来设置屏障以防止扩散；直接回收液体或储存在吸收剂中；用清洁剂、水和硬扫帚清洁污染区域，将收集的液体放入一次性容器中。 Use sand, mud or other materials that can be used as barriers to set up barriers to prevent diffusion. Recover liquid directly or store in absorbent. Clean the contaminated area with detergent, water and a hard broom. Put the collected liquid in a disposable container.
参考其他部分 Reference to other sections	有关安全处理的信息，请参阅第7节。 See Section 7 for information on safe handling. 有关个人防护设备的信息，请参阅第8节。 See Section 8 for information on personal protection equipment. 有关处置的信息见第13节。 See Section 13 for information on disposal.

第7部分 操作处置与储存
Section 7 Handling and storage

安全操作注意事项
Precautions for safe handling

防护措施 Protective measures	加强通风，操作人员必须经过专门培训，严格遵守操作规程。建议操作人员佩戴口罩、化学安全眼镜和橡胶手套。应急处理设备和合适的容器材料，以防止蒸汽泄漏。避免长时间或持续的皮肤接触。避免吸入蒸气和/或烟雾。 To strengthen ventilation, operators must undergo special training and strictly abide by the operating regulations. It is recommended that operators wear face masks, chemical safety glasses, and rubber gloves. Emergency treatment equipment and suitable containment materials to prevent steam leakage. Avoid prolonged or continuous skin contact. Avoid inhaling vapors and/or fumes.
职业卫生建议 Advice on general occupational hygiene	不要在工作区域吃东西、喝水和吸烟。使用后洗手。在进入饮食区之前，脱掉受污染的衣服和防护设备。 Do not eat, drink and smoke in work areas. Wash hands after use. Remove contaminated clothing and protective equipment before entering eating areas.
安全存储条件，包括不相容的物质 Conditions for safe storage, including any incompatibilities	将容器密闭，置于阴凉通风处。使用贴有标签且可密封的容器。储存温度：长期储存（3个月以上）-15 ~ 50°C；短期储存 -20 ~ 60 °C。容器或容器内衬应采用低碳钢或高密度聚乙烯。避免在容器或容器内层使用PVC。 Keep container tightly closed in a cool and well-ventilated place. Use properly labeled and sealable containers. Storage temperature: long-term storage (more than 3 months) -15 ~ 50 °C; short-term storage -20 ~ 60 °C. For the container or container lining, mild steel or high-density polyethylene should be used. Avoid using PVC in the container or the inner layer of the container.

特殊用途
Specific end use(s) : 不适用。
Not available.

第8部分 接触控制和个体防护
Section 8 Exposure Controls/Personal Protection

危害组成及职业接触限值
Composition and occupational exposure limits

化学品名称 Chemical Name	化学文摘登记号 CAS No.	数值的类型 (接触形式) Type of numerical value (contact	控制参数 / 容许浓度 Occupational Exposure Limit	依据 Basis
乙二醇 Ethylene Glycol	107-21-1	PC-TWA	20 mg/m³	CN OEL
		PC-STEL	40 mg/m³	CN OEL
		TWA(蒸气) TWA (steam)	25 ppm	ACGIH
		STEL(蒸气) STEL (steam)	50 ppm	ACGIH
		STEL(可吸入性粉尘, 仅气溶胶) STEL (respirable dust, aerosol only)	10 mg/m³	ACGIH

工程控制
Engineering controls : 确保充分通风。采取技术措施以符合职业接触限值。
Ensure adequate ventilation.Apply technical measures to comply with the occupational exposure limits.

个人防护措施
Individual protection measures

眼睛/面部防护
Eye/face protection : 如果可能发生飞溅，请佩戴护目镜或全面罩。
If splashing may occur,wear safety goggles or a full face mask.

手部防护
Hand protection : 戴上防护手套。适用材料：PVC、氯丁橡胶或丁腈橡胶手套。
Wear protective gloves.Suitable material:PVC,Neoprene or nitrile rubber gloves.

身体防护
Body protection : 耐化学品实验服。PVC 实验服/靴子，氯丁橡胶以防灰尘。
Chemical resistant apron.Apron/boots of PVC,neoprene in case of dusts.

呼吸系统防护
Respiratory protection : 在正常使用条件下，一般不需要佩戴呼吸防护设备。如果工程控制设施不能将空气浓度维持在足以保护人员健康的水平，请选择适合使用条件并符合相关法律要求的呼吸防护设备。如果您需要佩戴安全过滤式口罩，请选择合适的口罩和过滤器组合，选择适合微粒/有机气体和蒸气混合物的过滤器（沸点 >65°C）。
Under normal conditions of use, it is generally not necessary to wear respiratory protection equipment. If the engineering control facility does not maintain the air concentration at a level sufficient to protect the health of personnel, choose respiratory protection equipment suitable for the conditions of use and in compliance with relevant legal requirements. If you need to wear a safety filter mask, please choose a suitable mask and filter combination. Choose a filter suitable for a mixture of particulate/organic gas and vapor [boiling point > 65°C(149 °F)].

热危害
Thermal hazards : 穿戴合适的防护服以防止受热。
Wear suitable protective clothing to prevent heat.

环境暴露控制
Environmental exposure controls : 避免排放到环境中。
Avoid discharge into the environment.
根据当地法规、联邦和官方法规。
According to local regulations, Federal and official regulations.

第9部分 理化特性
Section 9 Physical and chemical properties

外观与性状
Appearance : 无沉淀及悬浮物、清亮透明液体。
No sediment and suspended materials, bright and clear transparent solution.

颜色
Colour : 红色
Red

气味
Odour : 无刺激性异味
No pungent peculiar odour

气味阈值
Odour threshold : 不适用
Not available.

pH : 7.0-10.0

凝固点
Freezing point : ≤-35°C

沸点
Boiling point : ≥107.5°C

闪点
Flash point : 不适用
Not available.

蒸发速率
Evaporation rate : 不适用
Not available.

易燃性(固体,气体)
Flammability (solid, gas) : 不适用
Not available.

易燃(液体)
Flammability limit : 不适用
Not available.

爆炸上限 / 可燃性上限
Upper explosive limits : 15.3 %(乙二醇)
15.3 %(ethylene glycol)

爆炸下限 / 可燃性下限
Lower explosive limits : 3.2 %(乙二醇)
3.2 %(ethylene glycol)

蒸气压
Vapour pressure : 不适用
Not available.

蒸气密度 Vapour density	:	不适用 Not available.
密度/相对密度 Relative Density	:	≥1.060(20°C)
电导率 Conductivity		≤100μs/cm
水溶性 Water solubility	:	溶于冷水 (20°C) Soluble in cold water (20°C)
正辛醇/水分配系数 n-Octanol/Water	:	不适用 Not available.
自燃温度 Auto-ignition temperature	:	不适用 Not available.
分解温度 Decomposition temperature	:	不适用 Not available.
运动黏度 Viscosity, dynamic	:	不适用 Not available.
爆炸特性 Explosive properties	:	无爆炸性 Nonexplosive
氧化性 Oxidising properties	:	此物质或混合物不被分类为氧化剂。 This substance or mixture is not classified as an oxidant.

第10部分 稳定性和反应性
Section 10 Stability and reactivity

反应性 Reactivity	:	该物质在正常储存和处理条件下是稳定的。 The substance is stable under normal storage and handling conditions.
稳定性 Chemical stability	:	在正常储存和处理条件下，在密闭容器中室温下稳定。 Stable at room temperature in closed containers under normal storage and handling conditions.
危险反应 Possibility of hazardous reactions	:	没有已知的危险反应。 No dangerous reactions known.
应避免的条件 Conditions to avoid	:	不相容的材料。极端温度和阳光直射。 Incompatible materials. Extreme temperature and direct sunlight.
禁配物 Incompatible materials	:	强氧化剂。 Strong oxidizing agents.
危险的分解产物 Hazardous decomposition products	:	一氧化碳，无法识别的有机和无机化合物。 Carbon monoxide, unrecognized organic and inorganic compounds.

第11部分 毒理学信息
Section 11 Toxicological information

接触途径 **Contact route**	:	吸入 In case of inhalation 皮肤接触 In case of skin contact 食入 In case of eyes contact 眼睛接触 In case of ingestion
急性毒性 **Acute toxicity**		吞咽有害。 Harmful to swallow.
产品 **Product**		
急性经口毒性 Acute oral toxicity	:	急性毒性估计值：1,191 mg/kg Estimated acute toxicity：1,191 mg/kg 方法：计算方法 Methods: Calculation method.
组分 **Component**		
乙二醇 **Ethylene glycol**		
急性经口毒性 Acute oral toxicity	:	急性毒性估计值：500mg/kg Estimated acute toxicity：500mg/kg 方法：专家意见 Methods: Expert opinion.
急性吸入毒性 Acute inhalation toxicity	:	LC50 (大鼠)：> 2.5 mg/l LC50 (rat): > 2.5 mg/L 暴露时间：6 小时 Exposure time: 6 hours 测试环境：粉尘/烟雾 Test environment: dust/smoke
急性经皮毒性 Acute percutaneous toxicity	:	LD50 (小鼠)：> 3,500 mg/kg LD50 (mice): > 3,500 mg/kg
皮肤腐蚀/刺激 **Skin corrosion/irritation**		根据现有信息无需进行分类。 According to the existing information, classification is unnecessary.
组分 **Component**		
乙二醇 **Ethylene glycol**		

种属 Species	:	家兔 Rabbit
结果 Result	:	无皮肤刺激 No skin irritation

严重眼睛损伤/眼刺激
Serious eye injury/eye irritation

根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

组分
Component

乙二醇
Ethylene glycol

种属 Species	:	家兔 Rabbit
结果 Result	:	无眼睛损伤/眼刺激 No eye injury/eye irritation

呼吸或皮肤过敏
Respiratory or skin allergy

根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

组分
Component

乙二醇
Ethylene glycol

测试类型 Test type	:	最大反应试验 Maximum response test
接触途径 Contact route	:	皮肤接触 Skin contact
种属 Species	:	豚鼠 Guinea pig
结果 Result	:	阴性 Negative

生殖细胞致突变性
Germ cell mutagenicity

根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

组分
Component

乙二醇
Ethylene glycol

体外基因毒性
In vitro genotoxicity

测试类型 Test type	:	细菌回复突变试验 (AMES) Bacterial reversion mutation test (AMES)
方法 Methods	:	OECD测试导则 471 OECD test guideline 471
结果 Result	:	阴性 Negative

致癌性
Carcinogenicity

根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

组分
Component

乙二醇
Ethylene glycol

种属 Species	:	小鼠 Mouse
染毒途径 Exposure route	:	食入 Ingestion
暴露时间 Duration of exposure	:	2 年 2 years
结果 Result	:	阴性 Negative

生殖毒性 Reproductive toxicity	:	根据现有信息无需进行分类。 According to the existing information, classification is unnecessary.
特异性靶器官系统毒性- 一次接触 STOT- single exposure	:	根据现有信息无需进行分类。 According to the existing information, classification is unnecessary.
特异性靶器官系统毒性- 反复接触 STOT-repeated exposure	:	根据现有信息无需进行分类。 According to the existing information, classification is unnecessary.

组分
Component

乙二醇
Ethylene glycol

接触途径 Contact route	:	食入 Ingestion
靶器官 Target organ	:	肾 Kidney
评估 Estimate	:	在浓度10 -100 mg/kg体重时,在动物身上显示出产生了明显的健康影响。 When the concentration is 10 -100 mg/kg body weight, it shows obvious health effects on animals.

重复染毒毒性
Repeated toxicity 根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

组分
Component
乙二醇
Ethylene glycol

种属 Species	:	大鼠 Rat
NOAEL	:	150 mg/kg
染毒途径 Exposure route	:	食入 Ingestion
暴露时间 Duration of exposure	:	2 年 2 years
种属 Species	:	犬 Dog
NOAEL	:	2,200 - 4,400 mg/kg
染毒途径 Exposure route	:	皮肤接触 Skin contact
暴露时间 Duration of exposure	:	4 周 4 weeks
方法 Methods	:	OECD 测试导则 410 OECD test guideline 410

吸入危害
Aspiration hazard 根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

第12部分 生态学信息
Section 12 Ecological information

生态毒性
Toxicity : 根据现有信息无需进行分类。
According to the existing information, classification is unnecessary.

组分
Component
乙二醇
Ethylene glycol

对鱼类的毒性 Toxicity to fish		
LC50(肥头鲦鱼) LC50(Pimephales promelas)	:	72,860 mg/l
暴露时间 Duration of exposure	:	96 小时 96 hours
对水溞和其他水生无脊椎动物 For Daphnia and other aquatic invertebrates		
EC50 (水溞) EC50 (Daphnia magna)		> 100 mg/l
暴露时间 Duration of exposure	:	48 小时 48 hours
方法 Methods	:	OECD 测试导则 202 OECD test guideline 202
对藻类/水生植物的毒性 Toxicity to algae/aquatic plants		
EC50(绿藻) EC50(Pseudokirchneriella subcapitata)	:	6,500 -13,000 mg/l
暴露时间 Duration of exposure	:	96 小时 96 hours
对鱼类的毒性 (慢性毒性) Toxicity to fish (chronic toxicity)		
NOEC (肥头鲦鱼) NOEC(Pimephales promelas)	:	15,380 mg/l
暴露时间 Duration of exposure	:	7天 7 days
对水溞和其他水生无脊椎动物的毒性(慢性毒性) Toxicity to Daphnia and other aquatic invertebrates (chronic toxicity)		
NOEC (肥头鲦鱼) NOEC(Pimephales promelas)	:	8590 mg/l
暴露时间 Duration of exposure	:	7 天 7 days

持久性和降解性
Durability and degradability
组分
Component
乙二醇
Ethylene glycol
生物降解性
Biodegradability

结果 Result	快速生物降解的。 Rapidly biodegradable.

生物降解性 Biodegradability		90 - 100 %
暴露时间 Duration of exposure		10 天 10 days
方法 Methods		OECD 测试导则 301A OECD test guideline 301A

生物蓄积潜力
Biological accumulation potential
组分
Component
乙二醇
Ethylene glycol
生物蓄积
Biological accumulation

种属 Species	:	高体雅罗鱼 Leuciscus idus
生物富集系数(BCF) Bioconcentration factors (BCF)	:	10
正辛醇/水分配系数(Log Pow) N-Octanol/Water Partition Coefficient(Log Pow)	:	-1.93
土壤中的迁移性 **Mobility in soil**	:	会溶于水。如果本产品侵入土壤，由于其高流动性，可能会污染地下水。 Will dissolve in water. If this product invades the soil, it may pollute the groundwater because of its high mobility.
其他环境有害作用 **Other harmful effects on the environment**	:	不适用 Not available.

第13部分 废弃处置
Section 13 Disposal considerations

处置方法 **Waste treatment methods**	:	废弃处置前应参考国家和地方有关法规，采用回收/循环再造，否则建议采用焚化方法处理空容器可能含有有害残留物。不要在容器上或容器附近切割、穿刺或焊接。容器上的标签在清洗后才能取下。受污染的容器不能作为家庭废物处理。容器应以适当的方法清洁，或以填埋或焚化的方式处置。不要焚烧封闭容器。 Dispose of in accordance with all applicable local and national regulations. Use recovery/recycling where feasible, otherwise incineration is the recommended method of disposal. Empty containers may contain hazardous residues. Do not cut, puncture or weld on or near to the container. Labels should not be removed from containers until they have been cleaned. Contaminated containers must not be treated as household waste. Containers should be cleaned by appropriate methods and then re-used or

第14部分 运输信息
Section 14 Transport information

国际法规
International regulations
陆运(UNRTDG)
Land transport(UNRTDG)

联合国编号 UN number	:	不适用于供应的产品。 Not applicable to the supplied products.
联合国运输名称 UN Proper shipping name	:	不适用于供应的产品。 Not applicable to the supplied products.
运输风险类别 Transport hazard Class(es)	:	不适用于供应的产品。 Not applicable to the supplied products.
次要危险性 Secondary danger	:	不适用于供应的产品。 Not applicable to the supplied products.
包装类别 Packing group	:	不适用于供应的产品。 Not applicable to the supplied products.
标签 Label	:	不适用于供应的产品。 Not applicable to the supplied products.

空运(IATA-DGR)
Air transport(IATA-DGR)

联合国编号 UN number	:	不适用于供应的产品。 Not applicable to the supplied products.
联合国运输名称 UN Proper shipping name	:	不适用于供应的产品。 Not applicable to the supplied products.
运输风险类别 Transport hazard Class(es)	:	不适用于供应的产品。 Not applicable to the supplied products.
次要危险性 Secondary danger	:	不适用于供应的产品。 Not applicable to the supplied products.
包装类别 Packing group	:	不适用于供应的产品。 Not applicable to the supplied products.
标签 Label	:	不适用于供应的产品。 Not applicable to the supplied products.
包装说明(货运飞机) Package description (cargo plane)	:	不适用于供应的产品。 Not applicable to the supplied products.
包装说明(客运飞机) Package description (passenger aircraft)	:	不适用于供应的产品。 Not applicable to the supplied products.

海运(IMDG-Code)
Sea transport(IMDG-Code)

联合国编号 UN number	:	不适用于供应的产品。 Not applicable to the supplied products.
联合国运输名称 UN Proper shipping name	:	不适用于供应的产品。 Not applicable to the supplied products.
运输风险类别 Transport hazard Class(es)	:	不适用于供应的产品。 Not applicable to the supplied products.
次要危险性 Secondary danger	:	不适用于供应的产品。 Not applicable to the supplied products.
包装类别 Packing group	:	不适用于供应的产品。 Not applicable to the supplied products.
标签 Label	:	不适用于供应的产品。 Not applicable to the supplied products.
EmS 表号 EmS meter number	:	不适用于供应的产品。 Not applicable to the supplied products.
海洋污染物(是/否) Marine pollutants (YES/NO)	:	不适用于供应的产品。 Not applicable to the supplied products.
按《MARPOL73/78 公约》附则 II 和 IBC 规则 Transport in bulk according to Annex II of Marpol and the IBC Code	:	不适用于供应的产品。 Not applicable to the supplied products.
国内法规 Domestic regulations	:	GB 6944/12268
联合国编号 UN number	:	不适用于供应的产品。 Not applicable to the supplied products.
联合国运输名称 UN Proper shipping name	:	不适用于供应的产品。 Not applicable to the supplied products.
运输风险类别 Transport hazard Class(es)	:	不适用于供应的产品。 Not applicable to the supplied products.
次要危险性 Secondary danger	:	不适用于供应的产品。 Not applicable to the supplied products.
包装类别 Packing group	:	不适用于供应的产品。 Not applicable to the supplied products.
标签 Label	:	不适用于供应的产品。 Not applicable to the supplied products.
特殊防范措施 Special precautions for user	:	不适用于供应的产品。 Not applicable to the supplied products.

第15部分 法规信息
Section 15 Regulatory information

适用法规 Applicable regulations	:	职业病防治法 Occupational disease prevention law

第16部分 其他信息
Section 16 Other information

参考文献 Key literature references and sources for data	:	内部技术数据,数据来源于原料 SDS、OECD eChem 门户网站搜索结果,以及欧洲化学品管理局,http: //echa.europa.eu/ Internal technical data, which comes from raw material SDS, search results of OECD eChem portal, and the European Chemicals Agency, http://echa.europa.eu/
日期格式 Date format	:	年-月-日 YYYY-MM-DD

缩略语和首字母缩写
Abbreviations and acronyms

ACGIH	:	美国政府工业卫生学家会议(ACGIH)之阈限值 (TLV) The threshold limit value (TLV) of ACGIH
CN OEL	:	工作场所有害因素职业接触限值 - 化学有害因素 Workplace hazardous factors occupational exposure limits-chemical hazardous factors
ACGIH / TWA	:	8 小时,时间加权平均值 8 hours, time-weighted average
ACGIH / STEL	:	短期暴露限制 Short-term exposure limit
CN OEL / PC-TWA	:	时间加权平均容许浓度 Time-weighted average allowable concentration
CN OEL / PC-STEL	:	短时间接触容许浓度 Permissible concentration short term exposure limit,pc stel

免责声明
Disclaimer

据我们所知及确信,本安全技术说明书(SDS)于发布之日提供的信息均准确无误。此信息只用作安全操作、使用、加工、存储、运输、处置和发布的指南,不代表任何类型的保证书或质量说明书。除文本规定外,此表提供的信息只与本 SDS 顶部确定的特定材料有关,当 SDS 中的材料与任何其他材料混合使用或用于任何流程时,此表的信息将无效。材料用户应审查在特定环境下所需使用的作、使用、加工和存储方式相关的信息和建议,包括用户最终产品 SDS 材料的适用性评估(如适用)。

To the best of our knowledge and belief, the information provided in this safety technical specification (SDS) on the date of publication is accurate. This information is only used as a guide for safe operation, use, processing, storage, transportation, disposal and release, and does not represent any kind of guarantee or quality specification. Unless otherwise specified in the text, the information provided in this table is only related to the specific materials identified at the top of this SDS. When the materials in SDS are mixed with any other materials or used in any process, the information in this table will be invalid. Materials users should review the information and suggestions related to the working, using, processing and storage methods needed in specific environment, including the suitability evaluation of SDS materials as the final product of users (if applicable).

SAFETY DATA SHEET
according to GB/T 16483 and GB/T 17519

HFC-32 Refrigerant

Version	Revision Date:	SDS Number:	Date of last issue: 2022/07/07
6.5	2023/04/14	1329112-00040	Date of first issue: 2017/02/27

1. PRODUCT AND COMPANY IDENTIFICATION

Product name : HFC-32 Refrigerant

SDS-Identcode : 130000016047

Manufacturer or supplier's details

Company : The Chemours Chemical (Shanghai) Co., Ltd.

Address : 9F, SCG Parkside, 868 Yinghua Road, Pudong New District 201204, Shanghai, China

Telephone : 86 400 8056 528

Emergency telephone number : 86 532 8388 9090

E-mail address : SDS.ChinaPSR@chemours.com

Telefax : 86 21 2612 0862

Recommended use of the chemical and restrictions on use

Recommended use : Propellant
Refrigerant

Restrictions on use : For professional users only.

2. HAZARDS IDENTIFICATION

Emergency Overview

Appearance : Liquefied gas
Colour : colourless
Odour : slight, ether-like

Extremely flammable gas. Contains gas under pressure; may explode if heated.

GHS Classification

Flammable gases : Category 1

Gases under pressure : Liquefied gas

GHS label elements

Hazard pictograms :

Signal word : Danger

Hazard statements : H220 Extremely flammable gas.
H280 Contains gas under pressure; may explode if heated.

Precautionary statements :

Prevention:

P210 Keep away from heat/ sparks/ open flames/ hot surfaces. No smoking.

Response:

P377 Leaking gas fire: Do not extinguish, unless leak can be stopped safely.
P381 Eliminate all ignition sources if safe to do so.

Storage:

P410 + P403 Protect from sunlight. Store in a well-ventilated place.

Physical and chemical hazards

Extremely flammable gas. Contains gas under pressure; may explode if heated.

Health hazards

Not classified based on available information.

Environmental hazards

Not classified based on available information.

Other hazards which do not result in classification

Vapours are heavier than air and can cause suffocation by reducing oxygen available for breathing.
Misuse or intentional inhalation abuse may cause death without warning symptoms, due to cardiac effects.
Rapid evaporation of the product may cause frostbite.
May displace oxygen and cause rapid suffocation.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substance / Mixture : Substance

Substance name : Difluoromethane

CAS-No. : 75-10-5

Components

Chemical name	CAS-No.	Concentration (% w/w)
Difluoromethane#	75-10-5	>= 99.9 -<= 100

Voluntarily-disclosed substance

4. FIRST AID MEASURES

General advice : In the case of accident or if you feel unwell, seek medical advice immediately.
When symptoms persist or in all cases of doubt seek medical

		advice.
If inhaled	:	If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.
In case of skin contact	:	Thaw frosted parts with lukewarm water. Do not rub affected area. Get medical attention immediately.
In case of eye contact	:	Get medical attention immediately.
If swallowed	:	Ingestion is not considered a potential route of exposure.
Most important symptoms and effects, both acute and delayed	:	May cause cardiac arrhythmia. Other symptoms potentially related to misuse or inhalation abuse are Cardiac sensitisation Anaesthetic effects Light-headedness Dizziness confusion Lack of coordination Drowsiness Unconsciousness Gas reduces oxygen available for breathing. Contact with liquid or refrigerated gas can cause cold burns and frostbite.
Protection of first-aiders	:	No special precautions are necessary for first aid responders.
Notes to physician	:	Because of possible disturbances of cardiac rhythm, catecholamine drugs, such as epinephrine, that may be used in situations of emergency life support should be used with special caution.

5. FIREFIGHTING MEASURES

Suitable extinguishing media	:	Water spray Alcohol-resistant foam Carbon dioxide (CO_2) Dry chemical
Unsuitable extinguishing media	:	None known.
Specific hazards during fire-fighting	:	Vapours may form flammable mixture with air Exposure to combustion products may be a hazard to health. If the temperature rises there is danger of the vessels bursting due to the high vapor pressure.
Hazardous combustion products	:	Hydrogen fluoride carbonyl fluoride

		Carbon oxides
Specific extinguishing methods	:	Use extinguishing measures that are appropriate to local circumstances and the surrounding environment. Fight fire remotely due to the risk of explosion. Use water spray to cool unopened containers. Leaking gas fire: Do not extinguish, unless leak can be stopped safely. Remove undamaged containers from fire area if it is safe to do so. Evacuate area.
Special protective equipment for firefighters	:	Wear self-contained breathing apparatus for firefighting if necessary. Use personal protective equipment.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures	:	Evacuate personnel to safe areas. Only trained personnel should re-enter the area. Remove all sources of ignition. Avoid skin contact with leaking liquid (danger of frostbite). Ventilate the area. Follow safe handling advice (see section 7) and personal protective equipment recommendations (see section 8).
Environmental precautions	:	Avoid release to the environment. Prevent further leakage or spillage if safe to do so. Retain and dispose of contaminated wash water.
Methods and materials for containment and cleaning up	:	Ventilate the area. Non-sparking tools should be used. Suppress (knock down) gases/vapours/mists with a water spray jet. Local or national regulations may apply to releases and disposal of this material, as well as those materials and items employed in the cleanup of releases. You will need to determine which regulations are applicable. Sections 13 and 15 of this SDS provide information regarding certain local or national requirements.

7. HANDLING AND STORAGE

Handling

Technical measures	:	Use equipment rated for cylinder pressure. Use a backflow preventative device in piping. Close valve after each use and when empty.
Local/Total ventilation	:	If sufficient ventilation is unavailable, use with local exhaust ventilation. If advised by assessment of the local exposure potential, use only in an area equipped with explosion-proof exhaust ventila-

tion.

Advice on safe handling : Avoid breathing gas.
Handle in accordance with good industrial hygiene and safety practice, based on the results of the workplace exposure assessment
Keep container tightly closed.
Wear cold insulating gloves/ face shield/ eye protection.
Valve protection caps and valve outlet threaded plugs must remain in place unless container is secured with valve outlet piped to use point.
Prevent backflow into the gas tank.
Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder.
Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems.
Close valve after each use and when empty. Do NOT change or force fit connections.
Prevent the intrusion of water into the gas tank.
Never attempt to lift cylinder by its cap.
Do not drag, slide or roll cylinders.
Use a suitable hand truck for cylinder movement.
Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.
Take precautionary measures against static discharges.
Take care to prevent spills, waste and minimize release to the environment.

Avoidance of contact : Oxidizing agents

Storage

Conditions for safe storage : Cylinders should be stored upright and firmly secured to prevent falling or being knocked over.
Separate full containers from empty containers.
Do not store near combustible materials.
Avoid area where salt or other corrosive materials are present.
Keep in properly labelled containers.
Keep tightly closed.
Keep in a cool, well-ventilated place.
Keep away from direct sunlight.
Store in accordance with the particular national regulations.
Keep away from heat and sources of ignition.

Materials to avoid : Do not store with the following product types:
Self-reactive substances and mixtures
Organic peroxides
Oxidizing agents
Flammable liquids
Pyrophoric liquids
Pyrophoric solids
Self-heating substances and mixtures
Explosives

Recommended storage temperature	:	< 52 °C
Storage period	:	> 10 yr
Further information on storage stability	:	The product has an indefinite shelf life when stored properly.
Packaging material	:	Unsuitable material: None known.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Components with workplace control parameters

Contains no substances with occupational exposure limit values.

Engineering measures : Minimize workplace exposure concentrations.
If sufficient ventilation is unavailable, use with local exhaust ventilation.
If advised by assessment of the local exposure potential, use only in an area equipped with explosion-proof exhaust ventilation.

Personal protective equipment

Respiratory protection	:	If adequate local exhaust ventilation is not available or exposure assessment demonstrates exposures outside the recommended guidelines, use respiratory protection.
Filter type	:	Organic gas and low boiling vapour type
Eye/face protection	:	Wear the following personal protective equipment: Chemical resistant goggles must be worn. Face-shield
Skin and body protection	:	Wear the following personal protective equipment: If assessment demonstrates that there is a risk of explosive atmospheres or flash fires, use flame retardant antistatic protective clothing.
Hand protection		
Material	:	Heat resistant gloves
Remarks	:	Choose gloves to protect hands against chemicals depending on the concentration and quantity of the hazardous substance and specific to place of work. For special applications, we recommend clarifying the resistance to chemicals of the aforementioned protective gloves with the glove manufacturer. Wash hands before breaks and at the end of workday. Breakthrough time is not determined for the product. Change gloves often!

Protective measures	:	Wear cold insulating gloves/ face shield/ eye protection.
Hygiene measures	:	If exposure to chemical is likely during typical use, provide eye flushing systems and safety showers close to the working place. When using do not eat, drink or smoke. Wash contaminated clothing before re-use.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	:	Liquefied gas
Colour	:	colourless
Odour	:	slight, ether-like
Odour Threshold	:	No data available
pH	:	No data available
Melting point/freezing point	:	-136 °C
Initial boiling point and boiling range	:	-51.6 °C
Flash point	:	Not applicable
Evaporation rate	:	> 1 (CCL4=1.0)
Flammability (solid, gas)	:	Flammable
Self-ignition	:	The substance or mixture is not classified as pyrophoric.
Upper explosion limit / Upper flammability limit	:	Upper flammability limit 31 %(V) Method: ASTM E681
Lower explosion limit / Lower flammability limit	:	Lower flammability limit 14 %(V) Method: ASTM E681
Vapour pressure	:	17,010 hPa (25 °C)
Relative vapour density	:	1.82 (Air = 1.0)
Relative density	:	0.96 (25 °C)

Density	:	0.961 g/cm³ (25 °C) (as liquid)
Solubility(ies) Water solubility	:	4.4 g/l (25 °C)
Partition coefficient: n-octanol/water	:	log Pow: 0.21 (25 °C)
Auto-ignition temperature	:	530 °C
Decomposition temperature	:	No data available
Viscosity Viscosity, kinematic	:	Not applicable
Explosive properties	:	Not explosive
Oxidizing properties	:	The substance or mixture is not classified as oxidizing.
Particle size	:	Not applicable

10. STABILITY AND REACTIVITY

Reactivity	:	Not classified as a reactivity hazard.
Chemical stability	:	Stable if used as directed. Follow precautionary advice and avoid incompatible materials and conditions.
Possibility of hazardous reactions	:	Vapours may form flammable mixture with air Can react with strong oxidizing agents. Flammable gas.
Conditions to avoid	:	Heat, flames and sparks.
Incompatible materials	:	Oxidizing agents
Hazardous decomposition products	:	No hazardous decomposition products are known.

11. TOXICOLOGICAL INFORMATION

Exposure routes	:	Inhalation Skin contact Eye contact

Acute toxicity

Not classified based on available information.

Components:

Difluoromethane:

Acute oral toxicity : Assessment: The substance or mixture has no acute oral toxicity

Acute inhalation toxicity : LC50 (Rat): > 520000 ppm
Exposure time: 4 h
Test atmosphere: gas
Method: OECD Test Guideline 403

No observed adverse effect concentration (Dog): 350000 ppm
Test atmosphere: gas
Remarks: Cardiac sensitisation

Lowest observed adverse effect concentration (Dog): > 350000 ppm
Test atmosphere: gas
Remarks: Cardiac sensitisation

Cardiac sensitisation threshold limit (Dog): > 735,000 mg/m3
Test atmosphere: gas
Remarks: Cardiac sensitisation

Acute dermal toxicity : Assessment: The substance or mixture has no acute dermal toxicity

Skin corrosion/irritation

Not classified based on available information.

Components:

Difluoromethane:

Result : No skin irritation

Serious eye damage/eye irritation

Not classified based on available information.

Components:

Difluoromethane:

Result : No eye irritation

Respiratory or skin sensitisation

Skin sensitisation

Not classified based on available information.

Respiratory sensitisation

Not classified based on available information.

Components:

Difluoromethane:

Exposure routes : Skin contact
Result : negative

Germ cell mutagenicity

Not classified based on available information.

Components:

Difluoromethane:

Genotoxicity in vitro : Test Type: Bacterial reverse mutation assay (AMES)
Method: OECD Test Guideline 471
Result: negative

Test Type: Chromosome aberration test in vitro
Method: OECD Test Guideline 473
Result: negative

Genotoxicity in vivo : Test Type: Mammalian erythrocyte micronucleus test (in vivo cytogenetic assay)
Species: Mouse
Application Route: inhalation (gas)
Method: OECD Test Guideline 474
Result: negative

Germ cell mutagenicity - Assessment : Weight of evidence does not support classification as a germ cell mutagen.

Carcinogenicity

Not classified based on available information.

Reproductive toxicity

Not classified based on available information.

Components:

Difluoromethane:

Effects on fertility : Species: Mouse
Application Route: Inhalation
Result: negative
Remarks: Based on data from similar materials

Effects on foetal development : Test Type: Combined repeated dose toxicity study with the reproduction/developmental toxicity screening test
Species: Rat
Application Route: inhalation (gas)
Method: OECD Test Guideline 414
Result: negative

Test Type: Combined repeated dose toxicity study with the reproduction/developmental toxicity screening test
Species: Rabbit

Application Route: inhalation (gas)
Method: OECD Test Guideline 414
Result: negative

Reproductive toxicity - Assessment : Weight of evidence does not support classification for reproductive toxicity

STOT - single exposure

Not classified based on available information.

Components:

Difluoromethane:

Exposure routes : inhalation (gas)
Assessment : No significant health effects observed in animals at concentrations of 20000 ppmV/4h or less

STOT - repeated exposure

Not classified based on available information.

Components:

Difluoromethane:

Exposure routes : inhalation (gas)
Assessment : No significant health effects observed in animals at concentrations of 250 ppmV/6h/d or less.

Repeated dose toxicity

Components:

Difluoromethane:

Species : Rat, male and female
NOAEL : 49100 ppm
LOAEL : > 49100 ppm
Application Route : inhalation (gas)
Exposure time : 13 Weeks
Method : OECD Test Guideline 413

Aspiration toxicity

Not classified based on available information.

Components:

Difluoromethane:

No aspiration toxicity classification

12. ECOLOGICAL INFORMATION

Ecotoxicity

Components:

Difluoromethane:

Toxicity to fish	:	LC50 (Fish): 1,507 mg/l Exposure time: 96 h Method: ECOSAR (Ecological Structure Activity Relationships)
Toxicity to daphnia and other aquatic invertebrates	:	EC50 (Daphnia (water flea)): 652 mg/l Exposure time: 48 h Method: ECOSAR (Ecological Structure Activity Relationships)
Toxicity to algae/aquatic plants	:	EC50 (green algae): 142 mg/l Exposure time: 96 h Method: ECOSAR (Ecological Structure Activity Relationships)

Persistence and degradability

Components:

Difluoromethane:

Biodegradability	:	Result: Not readily biodegradable. Method: OECD Test Guideline 301D

Bioaccumulative potential

Components:

Difluoromethane:

Partition coefficient: n-octanol/water	:	log Pow: 0.714

Mobility in soil

No data available

Other adverse effects

No data available

13. DISPOSAL CONSIDERATIONS

Disposal methods

Waste from residues	:	Dispose of in accordance with local regulations.
Contaminated packaging	:	Empty containers should be taken to an approved waste handling site for recycling or disposal. Empty pressure vessels should be returned to the supplier.

Empty containers retain residue and can be dangerous.
Do not pressurize, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, or other sources of ignition. They may explode and cause injury and/or death.
If not otherwise specified: Dispose of as unused product.

14. TRANSPORT INFORMATION

International Regulations

UNRTDG

UN number	:	UN 3252
Proper shipping name	:	REFRIGERANT GAS R 32
Class	:	2.1
Packing group	:	Not assigned by regulation
Labels	:	2.1

IATA-DGR

UN/ID No.	:	UN 3252
Proper shipping name	:	Refrigerant gas R 32
Class	:	2.1
Packing group	:	Not assigned by regulation
Labels	:	Flammable Gas
Packing instruction (cargo aircraft)	:	200
Packing instruction (passenger aircraft)	:	Not permitted for transport

IMDG-Code

UN number	:	UN 3252
Proper shipping name	:	REFRIGERANT GAS R 32
Class	:	2.1
Packing group	:	Not assigned by regulation
Labels	:	2.1
EmS Code	:	F-D, S-U
Marine pollutant	:	no

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code

Not applicable for product as supplied.

National Regulations

GB 6944/12268

UN number	:	UN 3252
Proper shipping name	:	REFRIGERANT GAS R 32
Class	:	2.1
Packing group	:	Not assigned by regulation
Labels	:	2.1

Special precautions for user

The transport classification(s) provided herein are for informational purposes only, and solely based upon the properties of the unpackaged material as it is described within this Safety Data Sheet. Transportation classifications may vary by mode of transportation, package sizes, and variations in regional or country regulations.

15. REGULATORY INFORMATION

National regulatory information

Regulations on Safety Management of Hazardous Chemicals

Catalogue of Hazardous Chemicals : Listed

Identification of Major Hazard Installations for Hazardous Chemicals (GB 18218)

No. / Code	Chemical name / Category	Threshold quantity
W2	Flammable gases	10 t

Montreal Protocol : Difluoromethane

Yangtze River Protection Law

This product does not contain any dangerous chemicals prohibited for inland river transport.

16. OTHER INFORMATION

Revision Date : 2023/04/14

Other information : Chemours™ and the Chemours Logo are trademarks of The Chemours Company.
Before use read Chemours safety information.
For further information contact the local Chemours office or nominated distributors.

Further information

Sources of key data used to compile the Safety Data Sheet : Internal technical data, data from raw material SDSs, OECD eChem Portal search results and European Chemicals Agency, http://echa.europa.eu/

Date format : yyyy/mm/dd

Full text of other abbreviations

AIIC - Australian Inventory of Industrial Chemicals; ANTT - National Agency for Transport by Land of Brazil; ASTM - American Society for the Testing of Materials; bw - Body weight; CMR - Carcinogen, Mutagen or Reproductive Toxicant; DIN - Standard of the German Institute for Standardisation; DSL - Domestic Substances List (Canada); ECx - Concentration associated with x% response; ELx - Loading rate associated with x% response; EmS - Emergency Schedule; ENCS - Existing and New Chemical Substances (Japan); ErCx - Concentration associated with x% growth rate response; ERG - Emergency Response Guide; GHS - Globally Harmonized System; GLP - Good Laboratory Practice; IARC - International Agency for Research on Cancer; IATA - International Air Transport Association; IBC - International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk; IC50 - Half maximal inhibitory concentration; ICAO - International Civil Aviation Organization; IECSC - Inventory of Existing Chemical Substances in China; IMDG - International Maritime Dangerous Goods; IMO - International Maritime Organization; ISHL - Industrial Safety and Health Law (Japan); ISO - International Organisation for Standardization; KECI - Korea Existing Chemicals Inventory; LC50 - Lethal Concentration to 50 % of a test population; LD50 - Lethal Dose to 50% of a test population (Median

Lethal Dose); MARPOL - International Convention for the Prevention of Pollution from Ships; n.o.s. - Not Otherwise Specified; Nch - Chilean Norm; NO(A)EC - No Observed (Adverse) Effect Concentration; NO(A)EL - No Observed (Adverse) Effect Level; NOELR - No Observable Effect Loading Rate; NOM - Official Mexican Norm; NTP - National Toxicology Program; NZIoC - New Zealand Inventory of Chemicals; OECD - Organization for Economic Co-operation and Development; OPPTS - Office of Chemical Safety and Pollution Prevention; PBT - Persistent, Bioaccumulative and Toxic substance; PICCS - Philippines Inventory of Chemicals and Chemical Substances; (Q)SAR - (Quantitative) Structure Activity Relationship; REACH - Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals; SADT - Self-Accelerating Decomposition Temperature; SDS - Safety Data Sheet; TCSI - Taiwan Chemical Substance Inventory; TDG - Transportation of Dangerous Goods; TECI - Thailand Existing Chemicals Inventory; TSCA - Toxic Substances Control Act (United States); UN - United Nations; UNRTDG - United Nations Recommendations on the Transport of Dangerous Goods; vPvB - Very Persistent and Very Bioaccumulative; WHMIS - Workplace Hazardous Materials Information System

Disclaimer

CN / EN

Opteon™ XP10 (R-513A) Refrigerant

SECTION 1. IDENTIFICATION

Product name : Opteon™ XP10 (R-513A) Refrigerant

SDS-Identcode : 130000051352

Other means of identification : No data available

Manufacturer or supplier's details

Company name of supplier : The Chemours Canada Company

Address : 151 Bloor Street West - 12th Floor
Toronto, ON M5S 1S4 Canada

Telephone : 1-844-773-CHEM (2436)

Emergency telephone : 1-866-595-1473 (24 hours)

Recommended use of the chemical and restrictions on use

Recommended use : Refrigerant

Restrictions on use : Consumer use, For professional users only.

SECTION 2. HAZARDS IDENTIFICATION

GHS classification in accordance with the Hazardous Products Regulations

Gases under pressure : Liquefied gas

Simple Asphyxiant : Category 1

GHS label elements

Hazard pictograms :

Signal Word : Warning

Hazard Statements : H280 Contains gas under pressure; may explode if heated.
May displace oxygen and cause rapid suffocation.

Precautionary Statements :

Storage:

P410 + P403 Protect from sunlight. Store in a well-ventilated place.

Other hazards

Vapors are heavier than air and can cause suffocation by reducing oxygen available for breathing.
Misuse or intentional inhalation abuse may cause death without warning symptoms, due to cardiac effects.
Rapid evaporation of the product may cause frostbite.

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Substance / Mixture : Mixture

Components

Chemical name	Common Name/Synonym	CAS-No.	Concentration (% w/w)
2,3,3,3-Tetrafluoropropene#	No data available	754-12-1	56
1,1,1,2-Tetrafluoroethane#	HFC-134a	811-97-2	44

Voluntarily-disclosed substance

SECTION 4. FIRST AID MEASURES

General advice : In the case of accident or if you feel unwell, seek medical advice immediately.
When symptoms persist or in all cases of doubt seek medical advice.

If inhaled : If inhaled, remove to fresh air.
If not breathing, give artificial respiration.
If breathing is difficult, give oxygen.
Get medical attention immediately.

In case of skin contact : Thaw frosted parts with lukewarm water. Do not rub affected area.
Get medical attention immediately.

In case of eye contact : Get medical attention immediately.

If swallowed : Ingestion is not considered a potential route of exposure.

Most important symptoms and effects, both acute and delayed : May cause cardiac arrhythmia.
Other symptoms potentially related to misuse or inhalation abuse are
Cardiac sensitization
Anaesthetic effects
Light-headedness
Dizziness
confusion
Lack of coordination
Drowsiness
Unconsciousness
Skin contact may provoke the following symptoms:
Irritation

		Swelling of tissue Itching Discomfort Redness Eye contact may provoke the following symptoms tearing Redness Discomfort May displace oxygen and cause rapid suffocation. Gas reduces oxygen available for breathing. Contact with liquid or refrigerated gas can cause cold burns and frostbite.
Protection of first-aiders	:	No special precautions are necessary for first aid responders.
Notes to physician	:	Because of possible disturbances of cardiac rhythm, catecholamine drugs, such as epinephrine, that may be used in situations of emergency life support should be used with special caution.

SECTION 5. FIRE-FIGHTING MEASURES

Suitable extinguishing media	:	Not applicable Will not burn
Unsuitable extinguishing media	:	Not applicable Will not burn
Specific hazards during fire fighting	:	Exposure to combustion products may be a hazard to health. If the temperature rises there is danger of the vessels bursting due to the high vapor pressure.
Hazardous combustion products	:	Hydrogen fluoride Fluorine compounds Carbon oxides carbonyl fluoride
Specific extinguishing methods	:	Use extinguishing measures that are appropriate to local circumstances and the surrounding environment. Fight fire remotely due to the risk of explosion. Use water spray to cool unopened containers. Remove undamaged containers from fire area if it is safe to do so. Evacuate area.
Special protective equipment for fire-fighters	:	Wear self-contained breathing apparatus for firefighting if necessary. Use personal protective equipment.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emer-	:	Evacuate personnel to safe areas. Avoid skin contact with leaking liquid (danger of frostbite).

gency procedures		Ventilate the area. Follow safe handling advice (see section 7) and personal protective equipment recommendations (see section 8).
Environmental precautions	:	Avoid release to the environment. Prevent further leakage or spillage if safe to do so. Retain and dispose of contaminated wash water.
Methods and materials for containment and cleaning up	:	Ventilate the area. Local or national regulations may apply to releases and disposal of this material, as well as those materials and items employed in the cleanup of releases. You will need to determine which regulations are applicable. Sections 13 and 15 of this SDS provide information regarding certain local or national requirements.

SECTION 7. HANDLING AND STORAGE

Technical measures	:	Use equipment rated for cylinder pressure. Use a backflow preventative device in piping. Close valve after each use and when empty.
Local/Total ventilation	:	Use only with adequate ventilation.
Advice on safe handling	:	Avoid breathing gas. Handle in accordance with good industrial hygiene and safety practice, based on the results of the workplace exposure assessment Wear cold insulating gloves/ face shield/ eye protection. Valve protection caps and valve outlet threaded plugs must remain in place unless container is secured with valve outlet piped to use point. Prevent backflow into the gas tank. Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Close valve after each use and when empty. Do NOT change or force fit connections. Prevent the intrusion of water into the gas tank. Never attempt to lift cylinder by its cap. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Keep away from heat and sources of ignition. Take precautionary measures against static discharges. Take care to prevent spills, waste and minimize release to the environment.
Conditions for safe storage	:	Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Separate full containers from empty containers. Do not store near combustible materials. Avoid area where salt or other corrosive materials are present.

		Keep in properly labeled containers. Keep in a cool, well-ventilated place. Keep away from direct sunlight. Store in accordance with the particular national regulations.
Materials to avoid	:	Do not store with the following product types: Self-reactive substances and mixtures Organic peroxides Oxidizing agents Flammable liquids Flammable solids Pyrophoric liquids Pyrophoric solids Self-heating substances and mixtures Substances and mixtures which in contact with water emit flammable gases Explosives Very acutely toxic substances and mixtures Acutely toxic substances and mixtures Substances and mixtures with chronic toxicity
Recommended storage temperature	:	< 52 °C
Storage period	:	> 10 y
Further information on storage stability	:	The product has an indefinite shelf life when stored properly.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Ingredients with workplace control parameters

Contains no substances with occupational exposure limit values.

Engineering measures	:	Ensure adequate ventilation, especially in confined areas. Minimize workplace exposure concentrations.

Personal protective equipment

Respiratory protection	:	If adequate local exhaust ventilation is not available or exposure assessment demonstrates exposures outside the recommended guidelines, use respiratory protection.
Filter type	:	Organic gas and low boiling vapor type
Hand protection Material	:	Low temperature resistant gloves
Remarks	:	Choose gloves to protect hands against chemicals depending on the concentration specific to place of work. For special applications, we recommend clarifying the resistance to che-

		micals of the aforementioned protective gloves with the glove manufacturer. Wash hands before breaks and at the end of workday. Breakthrough time is not determined for the product. Change gloves often!
Eye protection	:	Wear the following personal protective equipment: Chemical resistant goggles must be worn. Face-shield
Skin and body protection	:	Skin should be washed after contact.
Protective measures	:	Wear cold insulating gloves/ face shield/ eye protection.
Hygiene measures	:	If exposure to chemical is likely during typical use, provide eye flushing systems and safety showers close to the working place. When using do not eat, drink or smoke. Wash contaminated clothing before re-use.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	:	Liquefied gas
Color	:	colorless
Odor	:	slight, ether-like
Odor Threshold	:	No data available
pH	:	No data available
Melting point/freezing point	:	No data available
Initial boiling point and boiling range	:	-29.2 °C
Flash point	:	Not applicable
Evaporation rate	:	> 1 (CCL4=1.0)
Flammability (solid, gas)	:	Will not burn
Burning rate	:	15 mm/s
Upper explosion limit / Upper flammability limit	:	Upper flammability limit Method: ASTM E681 None.

Lower explosion limit / Lower flammability limit	:	Lower flammability limit Method: ASTM E681 None.
Vapor pressure	:	7,063.6 hPa (25 °C)
Relative vapor density	:	3.83 (Air = 1.0)
Relative density	:	1.17 (25 °C)
Solubility(ies) Water solubility	:	No data available
Partition coefficient: n-octanol/water	:	Not applicable
Autoignition temperature	:	No data available
Decomposition temperature	:	No data available
Viscosity Viscosity, kinematic	:	Not applicable
Explosive properties	:	Not explosive
Oxidizing properties	:	The substance or mixture is not classified as oxidizing.
Particle size	:	Not applicable

SECTION 10. STABILITY AND REACTIVITY

Reactivity	:	Not classified as a reactivity hazard.
Chemical stability	:	Stable if used as directed. Follow precautionary advice and avoid incompatible materials and conditions.
Possibility of hazardous reactions	:	Can react with strong oxidizing agents.
Conditions to avoid	:	This substance is not flammable in air at temperatures up to 100 °C (212 °F) at atmospheric pressure. However, mixtures of this substance with high concentrations of air at elevated pressure and/or temperature can become combustible in the presence of an ignition source. This substance can also become combustible in an oxygen enriched environment (oxygen concentrations greater than that in air). Whether a mixture containing this substance and air, or this substance in an oxygen enriched atmosphere become combustible depends on the inter-relationship of 1) the temperature 2) the pressure,

		and 3) the proportion of oxygen in the mixture. In general, this substance should not be allowed to exist with air above atmospheric pressure or at high temperatures; or in an oxygen enriched environment. For example this substance should NOT be mixed with air under pressure for leak testing or other purposes. Heat, flames and sparks.
Incompatible materials	:	Avoid impurities (e.g. rust, dust, ash), risk of decomposition. Incompatible with acids and bases. Incompatible with oxidizing agents. Oxygen Peroxides peroxide compounds Powdered metals
Hazardous decomposition products	:	No hazardous decomposition products are known.

SECTION 11. TOXICOLOGICAL INFORMATION

Information on likely routes of exposure

Inhalation
Skin contact
Eye contact

Acute toxicity

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

Acute inhalation toxicity	:	LC50 (Rat): > 405800 ppm Exposure time: 4 h Test atmosphere: gas Method: OECD Test Guideline 403 No observed adverse effect concentration (Dog): 120000 ppm Test atmosphere: gas Remarks: Cardiac sensitization Lowest observed adverse effect concentration (Dog): > 120000 ppm Test atmosphere: gas Remarks: Cardiac sensitization Cardiac sensitisation threshold limit (Dog): > 559,509 mg/m³ Test atmosphere: gas Remarks: Cardiac sensitization

1,1,1,2-Tetrafluoroethane:

Acute oral toxicity	:	Assessment: The substance or mixture has no acute oral toxicity

Acute inhalation toxicity	:	LC50 (Rat): > 567000 ppm Exposure time: 4 h Test atmosphere: gas Method: OECD Test Guideline 403 No observed adverse effect concentration (Dog): 40000 ppm Test atmosphere: gas Remarks: Cardiac sensitization Lowest observed adverse effect concentration (Dog): 80000 ppm Test atmosphere: gas Symptoms: May cause cardiac arrhythmia. Cardiac sensitisation threshold limit (Dog): 334,000 mg/m³ Test atmosphere: gas Symptoms: May cause cardiac arrhythmia.
Acute dermal toxicity	:	Assessment: The substance or mixture has no acute dermal toxicity

Skin corrosion/irritation

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

Result : No skin irritation

1,1,1,2-Tetrafluoroethane:

Result : No skin irritation

Serious eye damage/eye irritation

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

Result : No eye irritation

1,1,1,2-Tetrafluoroethane:

Result : No eye irritation

Respiratory or skin sensitization

Skin sensitization

Not classified based on available information.

Respiratory sensitization

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

Routes of exposure : Skin contact
Result : negative

1,1,1,2-Tetrafluoroethane:

Routes of exposure : Skin contact
Result : negative

Routes of exposure : Inhalation
Species : Rat
Result : negative

Routes of exposure : Inhalation
Species : Humans
Result : negative

Germ cell mutagenicity

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

Genotoxicity in vitro : Test Type: Bacterial reverse mutation assay (AMES)
Method: OECD Test Guideline 471
Result: positive

Test Type: Chromosome aberration test in vitro
Method: OECD Test Guideline 473
Result: negative

Genotoxicity in vivo : Test Type: Mammalian erythrocyte micronucleus test (in vivo cytogenetic assay)
Species: Mouse
Application Route: inhalation (gas)
Method: OECD Test Guideline 474
Result: negative

Test Type: In vivo mammalian alkaline comet assay
Species: Rat
Application Route: inhalation (gas)
Method: OECD Test Guideline 489
Result: negative

Test Type: Mammalian erythrocyte micronucleus test (in vivo cytogenetic assay)
Species: Rat
Application Route: inhalation (gas)
Method: OECD Test Guideline 474
Result: negative

Germ cell mutagenicity - : Weight of evidence does not support classification as a germ

Assessment cell mutagen.

1,1,1,2-Tetrafluoroethane:

Genotoxicity in vitro : Test Type: Bacterial reverse mutation assay (AMES)
Method: OECD Test Guideline 471
Result: negative

Test Type: Chromosome aberration test in vitro
Method: OECD Test Guideline 473
Result: negative

Genotoxicity in vivo : Test Type: Mammalian erythrocyte micronucleus test (in vivo cytogenetic assay)
Species: Mouse
Application Route: inhalation (gas)
Method: OECD Test Guideline 474
Result: negative

Test Type: Unscheduled DNA synthesis (UDS) test with mammalian liver cells in vivo
Species: Rat
Application Route: inhalation (gas)
Method: OECD Test Guideline 486
Result: negative

Germ cell mutagenicity - Assessment : Weight of evidence does not support classification as a germ cell mutagen.

Carcinogenicity

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

Result : negative

Carcinogenicity - Assessment : Weight of evidence does not support classification as a carcinogen

1,1,1,2-Tetrafluoroethane:

Species : Rat
Application Route : inhalation (gas)
Exposure time : 2 Years
Method : OECD Test Guideline 453
Result : negative

Carcinogenicity - Assessment : Weight of evidence does not support classification as a carcinogen

Reproductive toxicity

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

Effects on fertility	:	Test Type: Two-generation reproduction toxicity study Species: Rat Application Route: inhalation (gas) Method: OECD Test Guideline 416 Result: negative
Effects on fetal development	:	Test Type: Prenatal development toxicity study (teratogenicity) Species: Rat Application Route: inhalation (gas) Method: OECD Test Guideline 414 Result: negative
Reproductive toxicity - Assessment	:	Weight of evidence does not support classification for reproductive toxicity, No effects on or via lactation

1,1,1,2-Tetrafluoroethane:

Effects on fertility	:	Species: Mouse Application Route: Inhalation Result: negative
Effects on fetal development	:	Test Type: Combined repeated dose toxicity study with the reproduction/developmental toxicity screening test Species: Rabbit Application Route: inhalation (gas) Method: OECD Test Guideline 414 Result: negative
Reproductive toxicity - Assessment	:	Weight of evidence does not support classification for reproductive toxicity

STOT-single exposure

May displace oxygen and cause rapid suffocation.

Components:

2,3,3,3-Tetrafluoropropene:

Routes of exposure	:	inhalation (gas)
Assessment	:	No significant health effects observed in animals at concentrations of 20000 ppmV/4h or less

1,1,1,2-Tetrafluoroethane:

Routes of exposure	:	inhalation (gas)
Assessment	:	No significant health effects observed in animals at concentrations of 20000 ppmV/4h or less

STOT-repeated exposure

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

Routes of exposure	:	inhalation (gas)
Assessment	:	No significant health effects observed in animals at concentrations of 250 ppmV/6h/d or less.

1,1,1,2-Tetrafluoroethane:

Routes of exposure	:	inhalation (gas)
Assessment	:	No significant health effects observed in animals at concentrations of 250 ppmV/6h/d or less.

Repeated dose toxicity

Components:

2,3,3,3-Tetrafluoropropene:

Species	:	Rat, male and female
NOAEL	:	50000 ppm
LOAEL	:	>50000 ppm
Application Route	:	inhalation (gas)
Exposure time	:	13 Weeks
Method	:	OECD Test Guideline 413

1,1,1,2-Tetrafluoroethane:

Species	:	Rat, male and female
NOAEL	:	50000 ppm
LOAEL	:	>50000 ppm
Application Route	:	inhalation (gas)
Exposure time	:	2 y
Method	:	OECD Test Guideline 453

Aspiration toxicity

Not classified based on available information.

Components:

2,3,3,3-Tetrafluoropropene:

No aspiration toxicity classification

1,1,1,2-Tetrafluoroethane:

No aspiration toxicity classification

SECTION 12. ECOLOGICAL INFORMATION

Ecotoxicity

Components:

2,3,3,3-Tetrafluoropropene:

Toxicity to fish	:	LC50 (Cyprinus carpio (Carp)): > 197 mg/l Exposure time: 96 h Method: OECD Test Guideline 203
Toxicity to daphnia and other aquatic invertebrates	:	EC50 (Daphnia magna (Water flea)): > 100 mg/l Exposure time: 48 h Method: OECD Test Guideline 202
Toxicity to algae/aquatic plants	:	EC50 (Selenastrum capricornutum (green algae)): > 100 mg/l Exposure time: 72 h Method: OECD Test Guideline 201 NOEC (Selenastrum capricornutum (green algae)): > 75 mg/l Exposure time: 3 d Method: OECD Test Guideline 201

1,1,1,2-Tetrafluoroethane:

Toxicity to fish	:	LC50 (Oncorhynchus mykiss (rainbow trout)): 450 mg/l Exposure time: 96 h Method: Regulation (EC) No. 440/2008, Annex, C.1
Toxicity to daphnia and other aquatic invertebrates	:	EC50 (Daphnia magna (Water flea)): 980 mg/l Exposure time: 48 h Method: Regulation (EC) No. 440/2008, Annex, C.2
Toxicity to algae/aquatic plants	:	ErC50 (green algae): > 100 mg/l Exposure time: 96 h Remarks: Based on data from similar materials

Persistence and degradability

Components:

2,3,3,3-Tetrafluoropropene:

Biodegradability	:	Result: Not readily biodegradable. Method: OECD Test Guideline 301F

1,1,1,2-Tetrafluoroethane:

Biodegradability	:	Result: Not readily biodegradable. Method: OECD Test Guideline 301D

Bioaccumulative potential

Components:

2,3,3,3-Tetrafluoropropene:

Bioaccumulation	:	Remarks: Bioaccumulation is unlikely.
Partition coefficient: n-octanol/water	:	log Pow: 2 (25 °C)

1,1,1,2-Tetrafluoroethane:

Bioaccumulation	:	Remarks: Bioaccumulation is unlikely.
Partition coefficient: n-octanol/water	:	log Pow: 1.06

Mobility in soil

No data available

Other adverse effects

No data available

SECTION 13. DISPOSAL CONSIDERATIONS

Disposal methods

Waste from residues	:	Dispose of in accordance with local regulations.
Contaminated packaging	:	Empty containers should be taken to an approved waste handling site for recycling or disposal. Empty pressure vessels should be returned to the supplier. If not otherwise specified: Dispose of as unused product.

SECTION 14. TRANSPORT INFORMATION

International Regulations

UNRTDG

UN number	:	UN 1078
Proper shipping name	:	REFRIGERANT GAS, N.O.S. (2,3,3,3-Tetrafluoropropene, 1,1,1,2-Tetrafluoroethane)
Class	:	2.2
Packing group	:	Not assigned by regulation
Labels	:	2.2
Environmentally hazardous	:	no

IATA-DGR

UN/ID No.	:	UN 1078
Proper shipping name	:	Refrigerant gas, n.o.s. (2,3,3,3-Tetrafluoropropene, 1,1,1,2-Tetrafluoroethane)
Class	:	2.2
Packing group	:	Not assigned by regulation
Labels	:	Non-flammable, non-toxic Gas
Packing instruction (cargo aircraft)	:	200
Packing instruction (passenger aircraft)	:	200

IMDG-Code

UN number	:	UN 1078
Proper shipping name	:	REFRIGERANT GAS, N.O.S. (2,3,3,3-Tetrafluoropropene, 1,1,1,2-Tetrafluoroethane)
Class	:	2.2

Packing group	:	Not assigned by regulation
Labels	:	2.2
EmS Code	:	F-C, S-V
Marine pollutant	:	no

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code

Not applicable for product as supplied.

Domestic regulation

TDG

UN number	:	UN 1078
Proper shipping name	:	REFRIGERANT GAS, N.O.S. (2,3,3,3-Tetrafluoropropene, 1,1,1,2-Tetrafluoroethane)
Class	:	2.2
Packing group	:	Not assigned by regulation
Labels	:	2.2
ERG Code	:	126
Marine pollutant	:	no

Special precautions for user

The transport classification(s) provided herein are for informational purposes only, and solely based upon the properties of the unpackaged material as it is described within this Safety Data Sheet. Transportation classifications may vary by mode of transportation, package sizes, and variations in regional or country regulations.

SECTION 15. REGULATORY INFORMATION

International Regulations

Montreal Protocol : 1,1,1,2-Tetrafluoroethane

SECTION 16. OTHER INFORMATION

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Full text of other abbreviations

AIIC - Australian Inventory of Industrial Chemicals; ANTT - National Agency for Transport by Land of Brazil; ASTM - American Society for the Testing of Materials; bw - Body weight; CMR - Carcinogen, Mutagen or Reproductive Toxicant; DIN - Standard of the German Institute for Standardisation; DSL - Domestic Substances List (Canada); ECx - Concentration associated with x% response; ELx - Loading rate associated with x% response; EmS - Emergency Schedule; ENCS - Existing and New Chemical Substances (Japan); ErCx - Concentration associated with x% growth rate response; ERG - Emergency Response Guide; GHS - Globally Harmonized System; GLP - Good Laboratory Practice; IARC - International Agency for Research on Cancer; IATA - International Air Transport Association; IBC - International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk; IC50 - Half maximal inhibitory concentration; ICAO - International Civil Aviation Organization; IECSC - Inventory of Existing Chemical Substances in China; IMDG - International Maritime Dangerous Goods; IMO - International Maritime Organization; ISHL - Industrial Safety and Health Law (Japan); ISO - International Organisation for Standardization; KECI - Korea Existing Chemicals Inventory; LC50 - Lethal Concentration to 50 % of a test population; LD50 - Lethal Dose to 50% of a test population (Median Lethal Dose); MARPOL - International Convention for the Prevention of Pollution from Ships; n.o.s. - Not Otherwise Specified; Nch - Chilean Norm; NO(A)EC - No Observed (Adverse) Effect Concentration; NO(A)EL - No Observed (Adverse) Effect Level; NOELR - No Observable Effect Loading Rate; NOM - Official Mexican Norm; NTP - National Toxicology Program; NZIoC - New Zealand Inventory of Chemicals; OECD - Organization for Economic Co-operation and Development; OPPTS - Office of Chemical Safety and Pollution Prevention; PBT - Persistent, Bioaccumulative and Toxic substance; PICCS - Philippines Inventory of Chemicals and Chemical Substances; (Q)SAR - (Quantitative) Structure Activity Relationship; REACH - Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals; SADT - Self-Accelerating Decomposition Temperature; SDS - Safety Data Sheet; TCSI - Taiwan Chemical Substance Inventory; TDG - Transportation of Dangerous Goods; TECI - Thailand Existing Chemicals Inventory; TSCA - Toxic Substances Control Act (United States); UN - United Nations; UNRTDG - United Nations Recommendations on the Transport of Dangerous Goods; vPvB - Very Persistent and Very Bioaccumulative; WHMIS - Workplace Hazardous Materials Information System

Sources of key data used to compile the Material Safety Data Sheet	:	Internal technical data, data from raw material SDSs, OECD eChem Portal search results and European Chemicals Agency, http://echa.europa.eu/
Revision Date	:	09/25/2023
Date format	:	mm/dd/yyyy

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and shall not be considered a warranty or quality specification of any type. The information provided relates only to the specific material identified at the top of this SDS and may not be valid when the SDS material is used in combination with any other materials or in any process, unless specified in the text. Material users should review the information and recommendations in the specific context of their intended manner of handling, use, processing and storage, including an assessment of the appropriateness of the SDS material in the user’s end product, if applicable.

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