TEST REPORT
AR24TEST162

Job 24/0127 - ID 5467 - Cat. 0

Investigation on the control of Lithium-NMC battery thermal runaway, based on specific test protocol

OVERALL TEST RESULT

PASS

Applicant: **FirePro Systems Ltd**
8 FALEAS STR., AGIOS ATHANASIOS - CY-4101 Limassol - CYPRUS

Standards:

Internal methods *Tests not related to standards, developed by laboratory or under client specification*

7 Oct 2024, Saronno (Italy)

Head of laboratory digital sign

Giuseppe Terzaghi
Firmato digitalmente da Giuseppe Terzaghi
Data: 2024.10.07 15:55:29 +02'00'

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ALBARUBENS srl

The legal representative ing. Giuseppe Terzaghi

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REPORT ABSTRACT

GENERAL

This report describes the execution and the result of the test described in the annexed document (BESS fire test protocol Technical File_edit.pdf).

The scope was the investigation of the behaviour of an extinguishing system in controlling the thermal runaway of Lithium batteries, NMC type.
The test rig simulated a full-scale energy storage system, protected by the fire-fighting system under test, in order to evaluate its efficiency.

There are not (yet) standardized test protocols for this situation, so the test was performed by the laboratory as an "internal method", under the guidance of the annexed document.
Albarubens's laboratory is accredited under ISO/IEC17025 for many similar tests; all the measurements, the procedures, and this reports were carried out following the principles of this standard.

For safety reasons, the testing location was by the company RT Cert srl, via dell'Artigianato, 9/13, 27020 Carbonara al Ticino PV, who has made available the appropriate space.
The instrumentation and the scientific direction were by Albarubens srl.

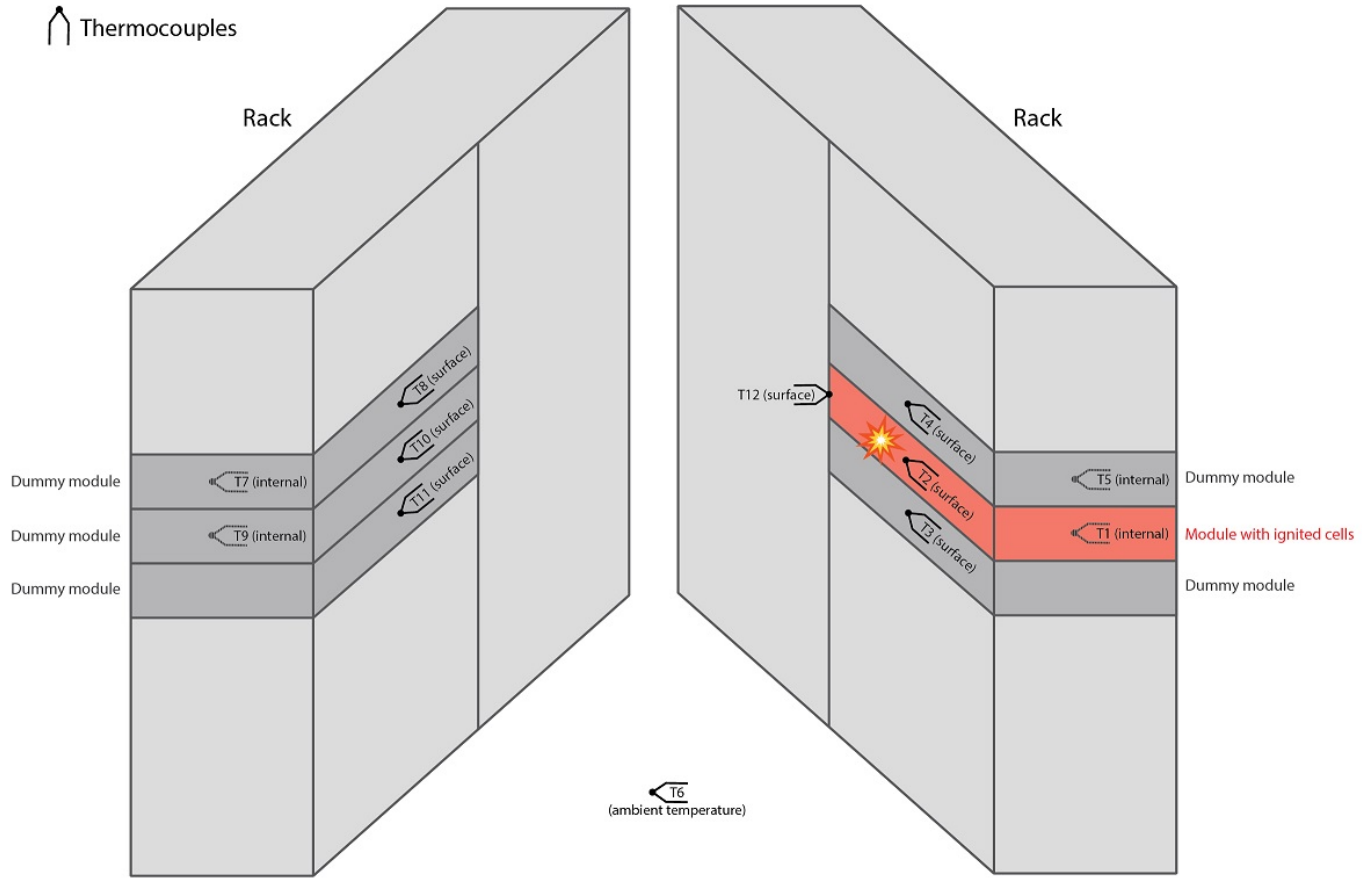
TESTING CONCEPT

1. The core of the setup is a battery housing containing the Lithium cells.
2. The surrounding battery housings were filled with expanded clay, in order to simulate the thermal capacity of the real ones (filled with cells in the real world).
3. N. 1 central cell was equipped with an ignition system (overcharging method), in order to start the thermal runaway.
4. In the first test, the system was protected by the FirePro aerosol generators combined with the Liion tablets.
5. In the second test, the system was protected only with FirePro aerosol generators.

For additional details, see the annexed document (test protocol).

TEMPERATURE PROBES

N. 12 K-type thermocouples were provided, recording the temperatures (see the diagrams in the report).



1. Internal volume of the active box (filled with batteries)
2. External surface of the active box
3. External surface of the box under the active one
4. External surface of the box over the active one
5. Internal volume of the box over the active one
6. Ambient temperature (air surrounding the boxes)
7. Internal volume of the box side/over the active one
8. External surface of the box side/over the active one
9. Internal volume of the box next (side) the active one
10. External surface of the box next (side) the active one
11. External surface of the box side/under the active one
12. Contact point between the active box and the rear one

The measuring system was complete of some thermal sticker, capable to register the peak temperature, having backup purposes only (no significant info).

CONCLUSIONS

a. The target cell was correctly ignited, starting its thermal runaway.
b. Accordingly with the literature data, this cell technology (NMC) developed high energy during the phenomenon (peak temperature was high).
c. The aerosol generators, with the addition of tablets during the first test, were activated.
d. In both the test, there was no propagation to the surrounding cells/modules.
e. In the test with tablets, the max temperature was significantly lower then in the test with generators only.

SAMPLE 2024407, MODEL:

Liion tablets inside battery housing and aerosol generators total flooding arrangement

See the report abstract

Cardinality: **n. 1 item** Internal ID: **14019** Accepted on: **19 Jul 2024** Accepted by: **Terzaghi**

Checked	Manufacturer:	**LGchem + FirePro**
Declared	Serial:	**NA**
Declared	Size/Weight:	**See the attached datasheet and test protocol**
Declared	Ratings:	**See the attached datasheet and test protocol**

Execution notes: **See the attached test protocol**
Samples origin: **Prototypes or unique specimens**
Acceptance notes: **See the attached test protocol**

Acceptance outcome: **PASS** (the sample is suitable for testing)

PERFORMED TESTS

Standard: Internal methods - Tests not related to standards, developed by laboratory or under client specification

SAMPLE ACCEPTANCE PICTURES

SAMPLE ACCEPTANCE PICTURES

Sample: 2024407 - picture #1
Modules positioned inside the battery housing

Sample: 2024407 - picture #2
Tablets positioned on the modules

Sample: 2024407 - picture #3
Aerosol generators in the testing chamber

(*) Internal methods § MI 93 Efficiency of fire suppression on Lithium batteries	PASS
NMC with generators and tablets	

Sample code: **2024407** Operator: Terzaghi Started on: 23 Jul 2024 Terminated on: 23 Jul 2024
Test ID: 2877 - Execution ID: 74643 Location:

[1]	Measurement	Value	Unit	[2]	Equipment range
I	Extinguishing method	Condensed aerosol generators and Liion tablets			
I	Type of battery in runaway	N. 7 NMC modules, 1.47x7=10.3kWh total			
S	Battery state of charge	Full (100%)			
S	Runaway ignition method	Single cell overcharging			
R	[I] Max temperature of module internal volume	353.8	°C	±1.49%	4.299 Multichannel Data Logger I - Temperature reading (over 25°C)
R	[I] Max temperature of external surface	187.8	°C	±1.49%	4.299 Multichannel Data Logger I - Temperature reading (over 25°C)
R	[I] Max temperature in the surrounding area	62.1	°C	±1.49%	4.299 Multichannel Data Logger I - Temperature reading (over 25°C)
R	[I] Propagation of runaway to surrounding batteries	NO			

[1] Type of parameter: I = Input parameter for the test, supplied by the client, the standard or a previous test
S = Setting - parameter applied to the sample in order to perform the test
R = Reading - measured or examined test result
O = Overall test result

[2] Measurement uncertainty, defined as a percentage of the value and estimated considering k=2 / 95%

[3] The fixed testing parameters are usually not reported, if provided by the standard; refer to its official original text

Standard acceptance criteria for this test:
The thermal runaway of the ignited cell doesn't propagate to the surrounding ones

Reasons because the declared outcome is 'PASS':
Full compliance with the acceptance criteria

Comments to test:
See the attached document (test protocol)

Auxiliary equipment used for test:
None

Sample: 2024407 - Picture #4
Extinguishing system on the ceiling

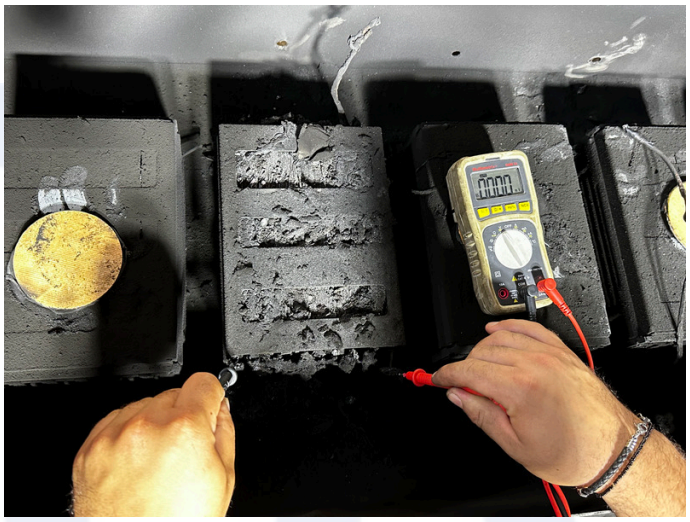
TEST PICTURES Sample: 2024407 - Test: Efficiency of fire suppression on Lithium batteries

Sample: 2024407 - Picture #5
Racks ready for the test

Sample: 2024407 - Picture #6
Modules after the test

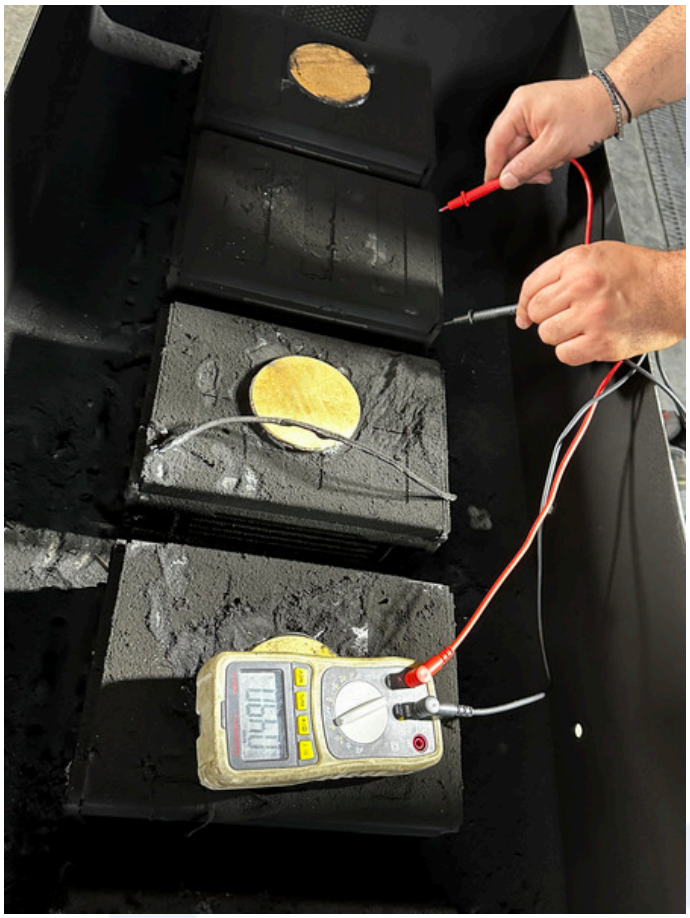
TEST PICTURES Sample: 2024407 - Test: Efficiency of fire suppression on Lithium batteries

Sample: 2024407 - Picture #7
Positioning the battery housing inside the rack



Sample: 2024407 - Picture #8
Ignited module, destroyed by the thermal runaway

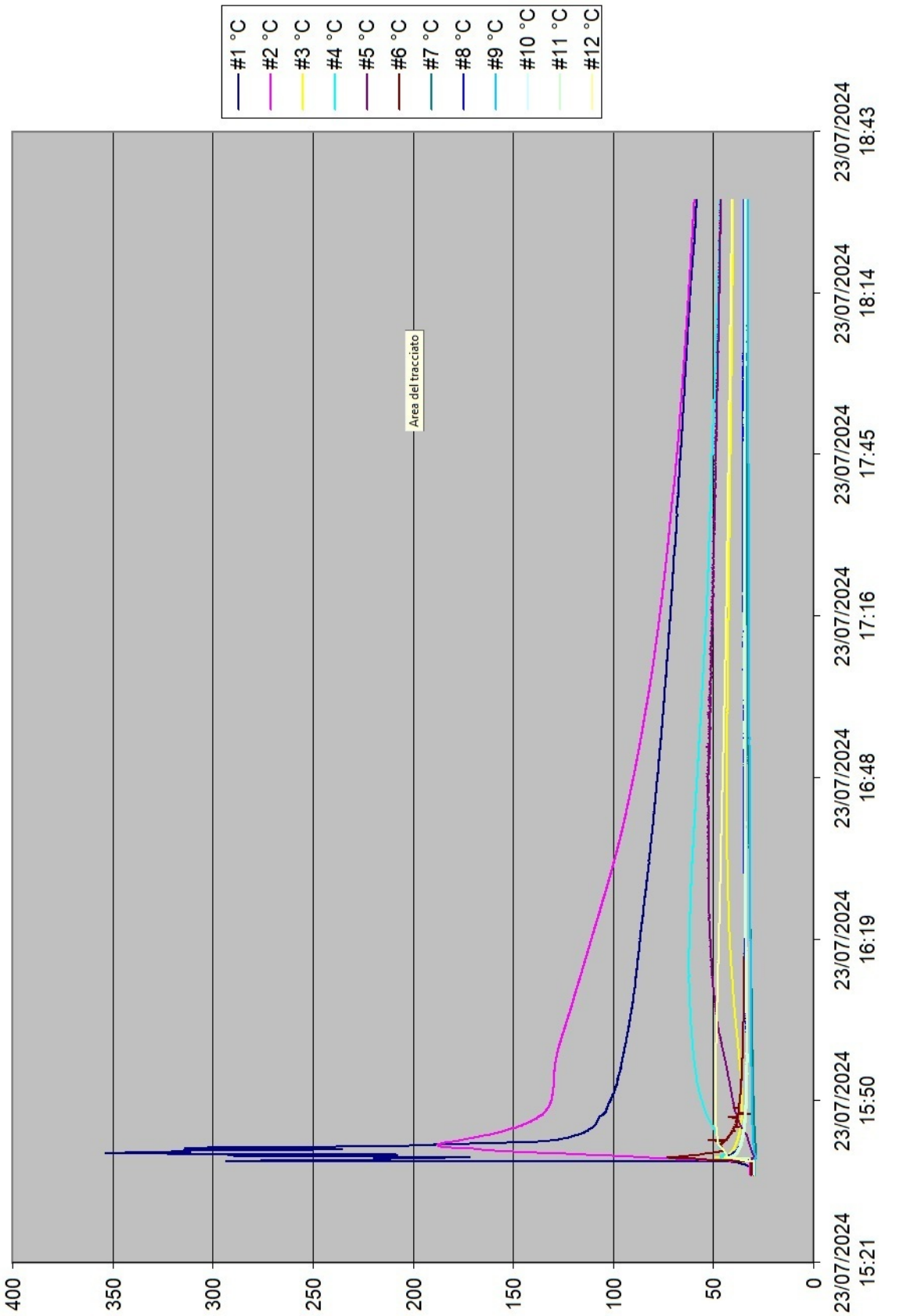
TEST PICTURES Sample: 2024407 - Test: Efficiency of fire suppression on Lithium batteries



Sample: 2024407 - Picture #9
Surrounding modules still working

TEST PICTURES Sample: 2024407 - Test: Efficiency of fire suppression on Lithium batteries - Picture #10

Trend of temperatures



SAMPLE 2024408, MODEL:

NMC cells with aerosol generators

See the report abstract

Cardinality: **n. 1 item** Internal ID: **14020** Accepted on: **19 Jul 2024** Accepted by: **Terzaghi**

Checked	Manufacturer:	**LGchem + FirePro**
Declared	Serial:	**NA**
Declared	Size/Weight:	**See the attached datasheet and test protocol**
Declared	Ratings:	**See the attached datasheet and test protocol**

Execution notes: **See the attached test protocol**
Samples origin: **Prototypes or unique specimens**
Acceptance notes: **See the attached test protocol**

Acceptance outcome: **PASS** (the sample is suitable for testing)

PERFORMED TESTS

Standard: Internal methods - Tests not related to standards, developed by laboratory or under client specification

SAMPLE ACCEPTANCE PICTURES

SAMPLE ACCEPTANCE PICTURES

Sample: 2024408 - picture #11
Modules positioned inside the battery housing

Sample: 2024408 - picture #12
Aerosol generators in the testing chamber

(*) Internal methods § MI 93
Efficiency of fire suppression on Lithium batteries

PASS

NMC with generators only

Sample code: **2024408** Operator: Terzaghi Started on: 24 Jul 2024 Terminated on: 24 Jul 2024
Test ID: 2877 - Execution ID: 74644 Location:

[1]	Measurement	Value	Unit	[2]	Equipment range
I	Extinguishing method	Standard aerosol generators			
I	Type of battery in runaway	N. 7 NMC modules, 1.47x7=10.3kWh total			
S	Battery state of charge	Full (100%)			
S	Runaway ignition method	Single cell overcharging			
R	[I] Max temperature of module internal volume	736.3	°C	±1.49%	4.299 Multichannel Data Logger I - Temperature reading (over 25°C)
R	[I] Max temperature of external surface	377.8	°C	±1.49%	4.299 Multichannel Data Logger I - Temperature reading (over 25°C)
R	[I] Max temperature in the surrounding area	147.2	°C	±1.49%	4.299 Multichannel Data Logger I - Temperature reading (over 25°C)
R	[I] Propagation of runaway to surrounding batteries	NO			

[1] Type of parameter: I = Input parameter for the test, supplied by the client, the standard or a previous test
S = Setting - parameter applied to the sample in order to perform the test
R = Reading - measured or examined test result
O = Overall test result

[2] Measurement uncertainty, defined as a percentage of the value and estimated considering k=2 / 95%

[3] The fixed testing parameters are usually not reported, if provided by the standard; refer to its official original text

Standard acceptance criteria for this test:
The thermal runaway of the ignited cell doesn't propagate to the surrounding ones

Reasons because the declared outcome is 'PASS':
Full compliance with the acceptance criteria

Comments to test:
See the attached document (test protocol)

Auxiliary equipment used for test:
None

Sample: 2024408 - Picture #13
Extinguishing system

Sample: 2024408 - Picture #14
Modules positioned inside the battery housing

TEST PICTURES Sample: 2024408 - Test: Efficiency of fire suppression on Lithium batteries

Sample: 2024408 - Picture #15
Battery housing with modules inside the rack

Sample: 2024408 - Picture #16
Racks ready for the test

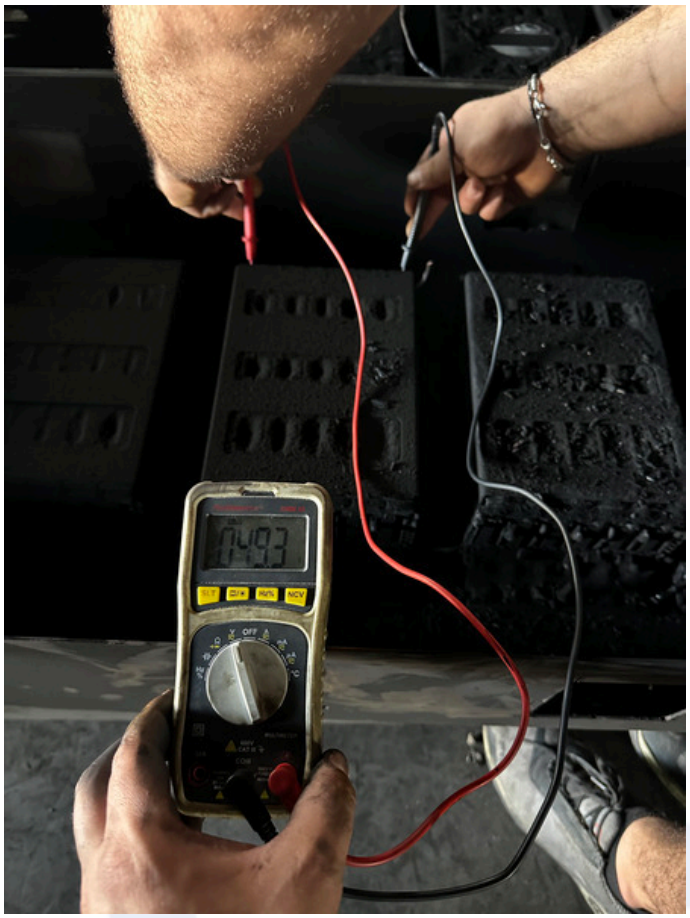
Sample: 2024408 - Picture #17
Control panel and instumentation equipment

TEST PICTURES Sample: 2024408 - Test: Efficiency of fire suppression on Lithium batteries

Sample: 2024408 - Picture #18
Thermal probes

Sample: 2024408 - Picture #19
Surrounding modules still working after the test

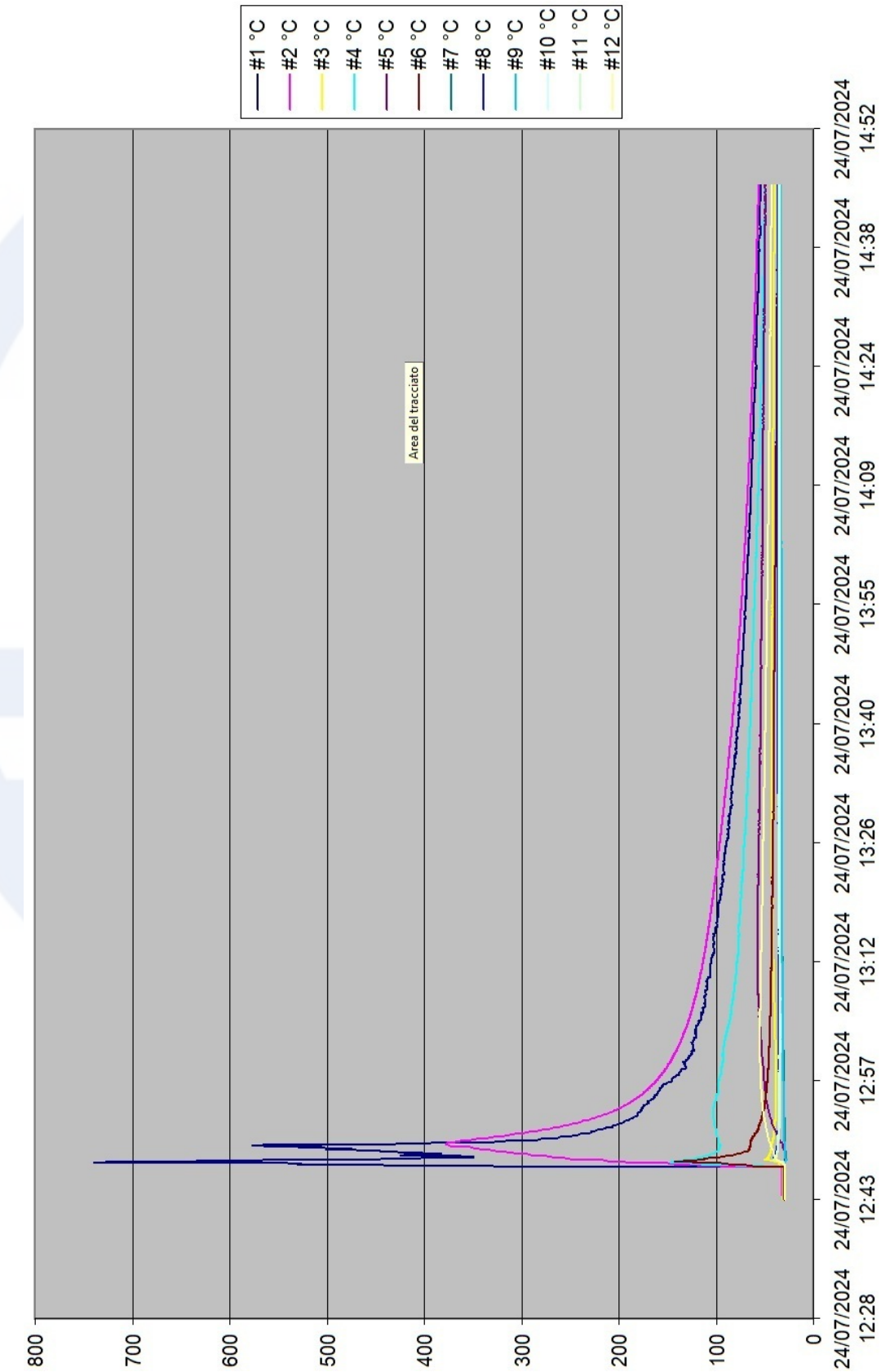
TEST PICTURES Sample: 2024408 - Test: Efficiency of fire suppression on Lithium batteries



Sample: 2024408 - Picture #20
Surrounding modules still working after the test

TEST PICTURES Sample: 2024408 - Test: Efficiency of fire suppression on Lithium batteries - Picture #21

Trend of temperatures



GENERAL INFO

Test report:	**AR24TEST162**
Title:	**Investigation on the control of Lithium-NMC battery thermal runaway, based on specific test protocol**
Issue date:	**7 Oct 2024**
Test performed by:	**Giuseppe Terzaghi**
Report generated by:	**the Albarubens WebApp - 1.124**
Report approved by:	**Simone Losa** (Laboratory management and tests performing)
Formal review by:	**Noemi Bolis** (Quality manager, Documents management, Project manager)
Report issued by:	(Legal representative of Albarubens)
Tests start date:	**23 Jul 2024** (Index test order corresponds to execution sequence)
Tests end date:	**24 Jul 2024** (See the result page for each test execution date)
Samples origin:	**Prototypes or unique specimens**
Acceptance dates:	**Sample 2024407 accepted on 19 Jul 2024 by Terzaghi** **Sample 2024408 accepted on 19 Jul 2024 by Terzaghi**
Description:	**---**
Draft approval:	**Client's mail on Oct, 7th 2024**
Revision history:	Report **AR24TEST162** dated **7 Oct 2024** *First issue*

GLOSSARY

COVER

Job: Reference to contract number
ID: Database identification number of the report
Cat: Place of execution of the tests: 0=internal laboratory, 3=external location
Overall test result: PASS= 100% of the samples and tests were successful
FAIL= 100% of the samples and tests gave negative results
DONE= 100% of the samples and tests don't have a specific acceptance criteria
PARTIALLY PASS (or FAIL)= more than 50% of the samples and tests gave positive (or negative) results
DONE/PASS (or similar)= part of tests without acceptance criteria, other part with declared result

CONTENT

PASS	Sample: the received item appears complete and without macroscopic defects Test: execution was successful, with result compliant to standard requirements or client's specifications
FAIL	Sample: presence of some anomalies making it possibly not suitable for testing and/or usage Test: correctly executed, but result is not compliant to standard requirements or client's specifications
DONE	Test concluded without macroscopic negative evidences, but a specific acceptance criteria is not applicable
NA	Not Applicable; typically it's a waived measurement
ND	Not Declared: the outcome is not (yet) evaluated by the laboratory
(*)	Test or comment not covered by ISO/IEC17025 accreditation
Declared	Information obtained by applicant's documentation
Checked	Information checked by the laboratory

ACCREDITATION

The tests included in this report are not covered by any accreditations, usually because they are very specific.
In any case, they were performed following the method provided by the international standard ISO/IEC 17025:2017.

The laboratory is accredited for a number of other tests by the internationally recognized US Accreditation Authority:

A2LA (USA) - American Association for Laboratory Accreditation
A2LA is the only independent, 501(c)3, non-profit, internationally-recognized accreditation body in the United States that offers a full range of comprehensive laboratory and laboratory-related accreditation services and training. A2LA is recognized globally, including European Union, because signatory of the ILAC agreement.

A2LA website: https://www.a2la.org

Details about the Albarubens laboratory accreditation scope can be found here: https://portal.a2la.org/scopepdf/4359-01.pdf

DISCLAIMERS

This document describes the result of tests and measurements performed on the samples submitted to the laboratory.

The reported results are exclusively referred to the described sample/s and in the specified conditions of measurement.
Any other extension of the results to other sample/s or other conditions of measurement are to be considered outside the scope of this document.
This test report is a restricted document, released only to the applicant and authorized people.
The partial replication of the present test report is forbidden if not authorized in writing by Albarubens.

This document is a 'test report': it shows the conditions and the result of tests and measurements performed by the laboratory
This document is not a 'certificate'; product certification requires additional investigation, not limited to technical issues.
The PASS/FAIL decision, if present, is attributed by the laboratory on the base of the declared acceptance criteria; it's for guidance only.
The final user (or the certification body, if any) may add further considerations, accepting the FAIL or discarding the PASS

In declaring PASS or FAIL, our General Policy is that laboratory does not take into account uncertainty, because we believe that it is already included in the safety factors provided by the standard.
In case of multiple or repeated measurements the acceptance criteria is compared with the arithmetic mean.
The criterion could vary in case of specific agreements with the customer or requirements from the reference standard.

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TEST CREDITS

TEST INFO

Standard: Internal methods - Tests not related to standards, developed by laboratory or under client specification

§ MI 93 Efficiency of fire suppression on Lithium batteries

CREDITS

This test is not accredited under ISO/IEC17025:2017, but performed following all the general rules.
To 7 Oct 2024, the laboratory performed exactly this test no.4 times.

This test belongs to the following Albarubens test family:

BATTERY ABUSE TESTING

Family including tests performed on batteries: ignition tests, propagation of flames, explosion of batteries/cells/modules/battery enclosures, tests with extinguishing systems, etc.

List of other tests belonging to the same family, shown for reference only:

- EN 60079-11:2012
  §10.5.3 Spark ignition and surface temperature of cells and batteries (Accredited under ISO/IEC17025:2017, performed no.56 times)
- Internal methods
  §MI 17 Short-circuiting test for batteries (Not accredited, performed no.5 times)
- IEC 60079-1:2014+COR1: 2018
  §E.3.5 General requirements for cells (or batteries) inside flameproof enclosures (Accredited under ISO/IEC17025:2017, performed no.4 times)
- IEC 60079-1:2014+COR1: 2018
  §E.4.1.1 Prevention of excessive temperature and cell damage - Flameproof enclosures (Accredited under ISO/IEC17025:2017, performed no.3 times)
- Internal methods
  §MI 49 Functional validation of ingition system for Lithium Battery/battery module (Not accredited, performed no.1 times)
- Internal methods
  §MI 53 Evaluation of characteristics of the explosion of a Lithium battery/battery module (Not accredited, performed no.4 times)
- Internal methods
  §MI 54 Effectiveness of extinguishing agent in controlling Lithium-Ion battery thermal runaway (Not accredited, performed no.15 times)
- Internal methods
  §MI 55 Functional evaluation of lithium battery estinguishing system (Not accredited, performed no.1 times)
- Internal methods
  §MI 57 Efficiency of ignition system for Lithium batteries thermal runaway (Not accredited, performed no.4 times)
- Internal methods
  §MI 61 Ignition of thermal runaway effect on consecutive cells of a Lithium battery module (Not accredited, performed no.6 times)
- Internal methods
  §MI 68 Validation of safety container for battery transport (Not accredited, performed no.13 times)
- IEC 60079-11:2023
  §9.14.3 Spark ignition and surface temperature of cells, batteries or supercapacitors (Accredited under ISO/IEC17025:2017, performed no.4 times)
- Internal methods
  §MI 90 Behaviour of a box in case of runaway of contained batteries (Not accredited, performed no.2 times)
- UL 1973:2010
  §8.3 Crush test (Not accredited, performed no.1 times)

INSTRUMENTS LIST

The laboratory manages the traceability to the international system and the calibration of all the instrumentation used, which is subjected to periodic verification of the calibration.
The following information is automatically extracted from our database, which also contains all relevant details, which however are confidential information.
Sometimes instruments are calibrated after use; this is perfectly normal and does not invalidate the measure, if the verification is positive.
The standard tolerance on expiration dates is 30 days.

Code	Name	Manufacturer	Model	Serial
4.299	Multichannel Data Logger I	Fluke	2638A/20/C240-3-14 Hydra III	44070049+45400260
	Last calibration was dated 12 Jul 2024	*Expiring on: 12 Jan 2025*	*Internal calibration ID: 12087*	
	'CalibrationReport_4_299_Multichannel Data Logger I.pdf' available for authorities or upon motivated request.			

EMBEDDED FILES

These files are part of the report, but not in PDF format; for this reason their content cannot be shown in printed copy.
Common PDF readers enable the double-click on the square icon, to download or to open them using the appropriate software.

Double click to download or to open the file 'NMC1.xls'

Double click to download or to open the file 'NMC2.xls'

End of document, signature on the cover - To check authenticity, download the original document from:

https://www.albarubens.it/authentication - Code: AR24TEST162 - Password: G4D65L

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LUCIANO BORGHETTI
LIFE SAFETY EXPERT SPECIALTY ENGINEERING

TECHNICAL FILE

INVESTIGATION ON FIREPRO CONDENSED AEROSOL SYSTEMS TO CONTROL AND INTERRUPT THE LITHIUM-POLYMER BATTERIES TERMAL RUNAWAY INSIDE A CONFINED SPACE

BATTERY **E**NERGY **S**TORAGE **S**YSTEMS **BESS** AND **B**ATTERY **I**NTENSIVE **S**TORAGE

PREPARED FOR

MANUFACTURER

FIREPRO SYSTEMS

PO BOX 54080, LIMASSOL,

CYPRUS - EU

DR G. GIANFILIPPI DE PARENTI

EXECUTIVE DIRECTOR

TEST LAB

ALBARUBENS SRL – www.albarubens.it

HEADQUARTER: VIA GAUDENZIO FERRARI 21/N, 21047 SARONNO (ITALY)

DR. ENG. GIUSEPPE TERZAGHI

PREPARED BY

LUCIANO BORGHETTI

LIFE SAFETY EXPERT

SPECIALTY ENGINEERING

INDEX OF CONTENTS

EXECUTIVE SUMMARY

This document “Technical File” is related to an “Internal Laboratory Test Method” to validate the capabilities of an “Integrated Fire Protection Technology” to “Control and Interrupt a Thermal Runaway in a BESS fitted with Lithium Polymers Batteries”.

This test procedure reproduces a “real world” of a typical basic size of a “BESS” and a “Generic Battery Storage”,

FirePro Condensed Aerosol Technology passed positively several test in different configuration/test protocols, proving the effectiveness of the FirePro technology to control and interrupt the Lithium-ion battery runaway.

The scope of this test is to assess the capability of the FirePro Condensed Aerosol Systems to control and interrupt the Lithium Polymer Battery runaway, inside a BESS and a Confined Space, reproducing the “real world” in full size/dimensions.

See “ANNEX A to C” for FirePro equipment and “ANNEX D” for the FirePro Patent Reference.

BACKGROUND

Excerpt from “LITHIUM-ION AND LITHIUM-POLYMERS BATTERIES RUNAWAY INVESTIGATION” by Luciano Borghetti

The kinetics of the Lithium-Polymers Batteries thermal runaway phenomenon are known from data and reports of public domain, including a number of experimental tests supported by FirePro Systems.

The Lithium Polymer Battery utilized for this test represent the worst case, due to the amount of gasified electrolyte generated during the thermal runaway event (each cell generates about 500 liters of gasified electrolyte).

The battery thermal runaway may result in serious fires and explosions having catastrophic results if the accident is not contained/controlled and the consequent fire is allowed to spread.

The battery thermal runaway is a consequence of the battery being subjected to “adverse effects”. It will create a heavy increase in the battery’s temperature, which will cause the electrolyte gasification and a subsequent rupture of the cells’ metal casing, or in case of lithium-polymers a rupture of the plastic pouch releasing the electrolyte gases. These vapors when in contact with the atmosphere burn (flash fire) at a very high temperature (in excess of 800ºC).

When subject to heating - thermal runaway - the battery cells’ burst suddenly.

The fire will involve in sequence the battery cells and the runaway may last for hours. Experience shows that batteries react for hours after the first incident, even when they are apparently under control.

Through tests performed, it is reported that 120ºC is the critical temperature at which the electrolyte will start to gasify. The battery shall be cooled down to 40ºC to interrupt the thermal runaway sequence, however the remaining power stored in the damaged battery poses an additional potential threat.

The electrolyte fire will generate substantial amount of HCl, HF, CO, HCN, and potentially SO_2 , H_2S and H_2 depending on the battery technology and the electrolyte technology.

The release of toxic and/or combustible or explosive substances during a fire can evolve forming an explosive mixture.

BESS AND LITHIUM POLYMERS BATTERIES ITENSIVE STORAGE

The use and installation of Battery Energy Storage Systems (BESS), as the Battery Intensive Storage (ready for sales) are rapidly increasing for a wide variety of uses.

The Lithium Polymers Batteries, also known as Lithium-ion Batteries (many different chemical technologies have been introduced into the market several years ago. The main advantage of them is represented by their higher energy density, compared to the existing batteries technologies and the technical developments are still in progress.

A typical BESS if formed by several Lithium Polymers Batteries connected, and the power electrical/electronic devices for charging the batteries and their management, identified as Battery Management System (BMS).

The BESS dimensions may range from small residential systems to a very large sizes in use in industry and installation requiring substantial power reserve.

The most recurrent layout is represented by a “Shipping Container Shape”, usually made by steel, as these BESS can be assembled in a workshop and moved by truck to the final installation site, the most used dimensions may vary from 10-feet, up to 40-feet long, 8 feet wide.

BESS AND BATTERIES INTENSIVE STORAGE RISK ANALYSIS

Thermal Runaway due to:

- Batteries aging and mismanagement.
- BMS failure resulting in Batteries overheating, and/or overcharging and/or over discharging.
- Failure of Ventilation or Exhaust System will result in a battery overheating.
- Short circuit on load side of BESS
- Failure of fire detection and suppression system
- Involvement of BESS by an external fire.

Fuel Classification:

<table>
<tr><th colspan="4">Classification of fires</th></tr>
<tr><th colspan="2">CEN Standard EN2</th><th colspan="2">NFPA 10</th></tr>
<tr><td>Class A</td><td>Fires of solid substances, mainly of an organic nature, which burn with the formation of embers</td><td>Class A</td><td>Fires in ordinary combustible materials such as wood, cloth, paper, rubber and many plastics.</td></tr>
<tr><td>Class B</td><td>Fires of liquid substances or substances that become liquid</td><td rowspan="2">Class B</td><td rowspan="2">Fires in flammable liquids, oils, greases, tars, oil base paints, lacquers and flammable gases</td></tr>
<tr><td>Class C</td><td>Fires of gases, e.g. methane, propane, hydrogen, acetylene, natural gas</td></tr>
<tr><td colspan="2"><u>Energized Electrical Fires</u>
According to EN2, electrical fires are not considered to constitute a fire class on their own, as electricity is a source of ignition that will feed the fire until removed. When the electrical supply has been isolated, the fire can be treated (generally) as ‘Class A’ for extinguishing purposes.</td><td>Class C</td><td>Fires, which involve energized electrical equipment where the electrical non-conductivity of the extinguishing medium is of importance. (When electrical equipment is de-energized, extinguishers for class A or B fires may be used safely.)</td></tr>
</table>

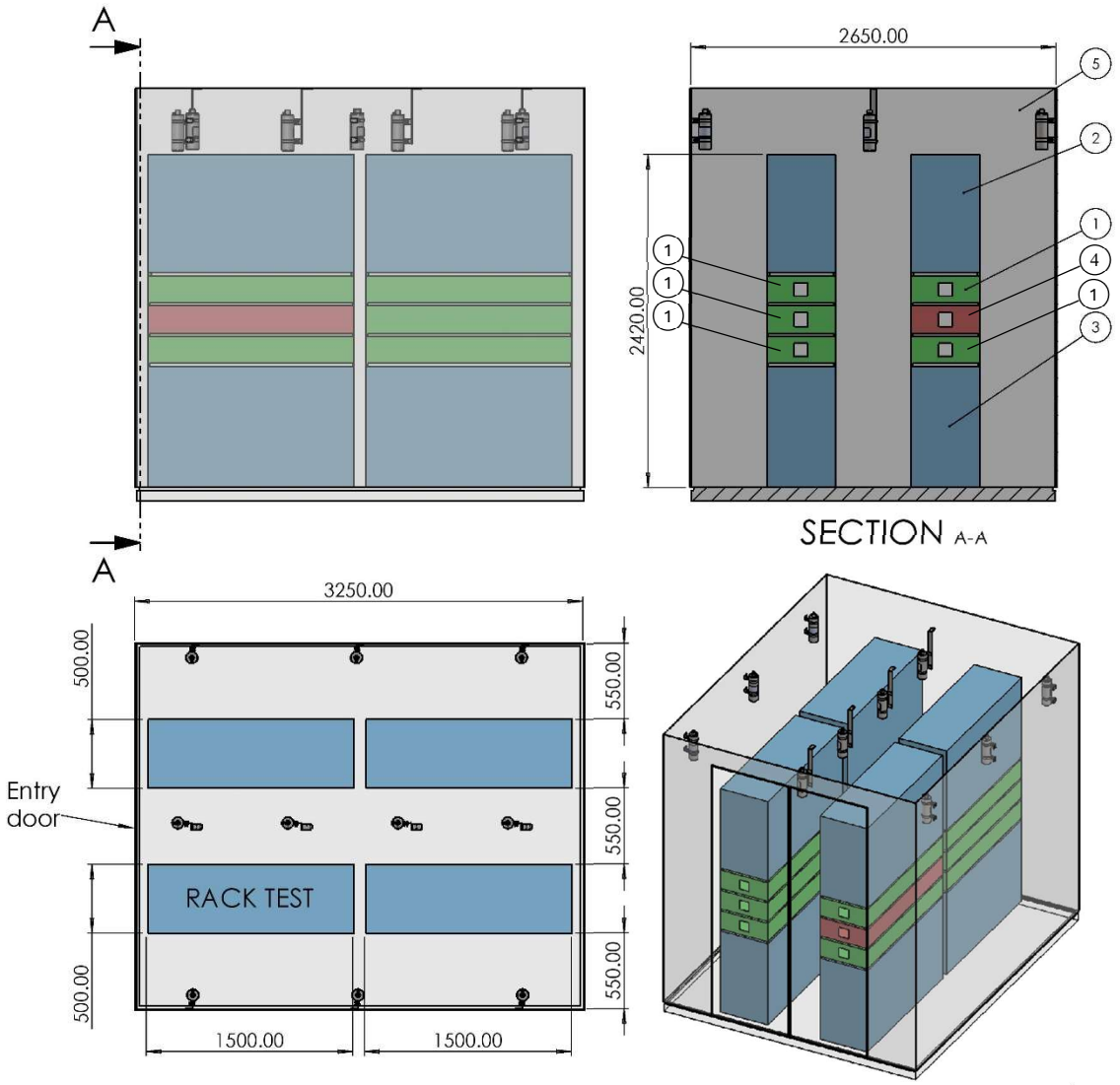
TEST SET UP

Test Rig:

The test arrangement (see Figures 1-3) reproduces the “Real World” of a full size “BESS Typical Housing Arrangement” in a steel container, with dimension of 10-feet long, 8-feet wide, 8.5-feet height a “10 feet; and a “Generic Battery Storage” for shipping or storing the “Lithium Polymer Batteries”.

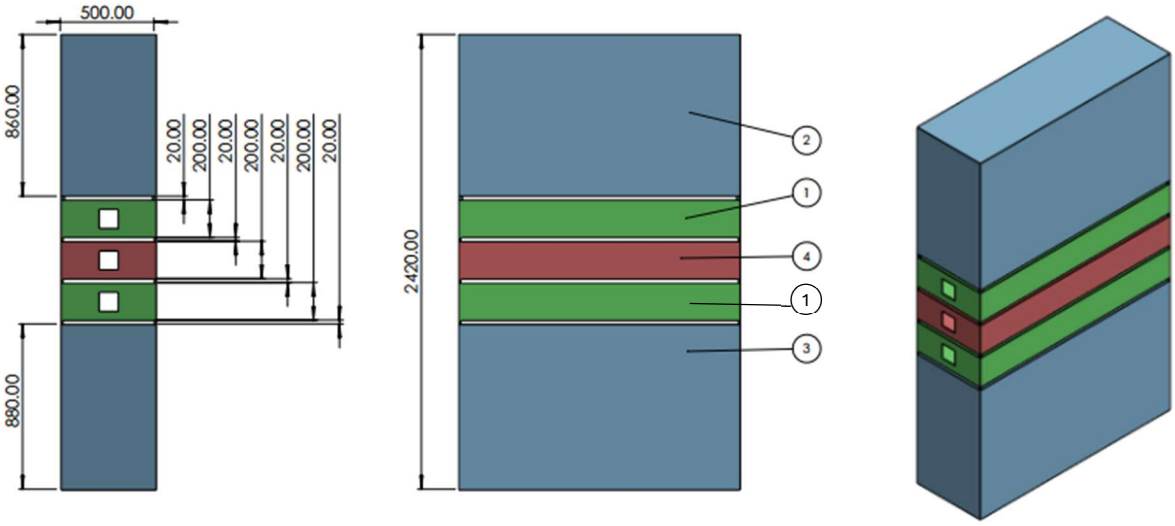
The rig is fitted with:

- 1 overpressure vent on the upper surface, for safety reasons, the thermal runaway phenomena may create a substantial overpressure.
- 4 battery racks of 11 dummy batteries in total.
  - The dummy batteries are reproduced with a steel box having L 1,500.00 mm, W 500.00 mm and H 200.00 mm. (Refer Item 1 in Figure 1)
  - Each dummy battery will be filled with ballast material having correct thermal capacitance.
  - Each dummy battery adjacent the “real BESS module” will be fitted with “thermal sensor”, to measure the temperatures inside and outside the dummy battery.
- 1 “real BESS module” will be placed on the central slot of one rack. (Refer Item 4 in Figure 1)
  - The “real BESS module” will be fitted with n.7 submodules (cells aggregate) for a total stored energy of 10.3kWh.
    - Lithium nickel manganese cobalt oxides (abbreviated NMC, Li-NMC, LNMC, or NCM)
    - Each submodule contains “NMC Pouch Type” cells (12s1p cells aggregate).
    - Submodule dimensions 160 (w) x 300 (l) x 180 (h) mm.
    - weight 10.0 kg
    - nominal voltage 32,4 (min.) / 44,4 (nom.) / 49,8 V (max.)
    - power 1.47 kWh
  - The “real BESS module” will be fitted with an overpressure device, for safety reasons, as the runaway will develop substantial overpressure.
  - The overpressure device will simulate the real overpressure device of the BESS module and/or will simulate the rupture of the BESS module casing in case the BESS module is not fitted with a overpressure device.
- Engineered Thermal Runaway Protection System Technology to be tested.
  - Early detection system
    - Optical Smoke Detector - Apollo Series 65 (Part No. 55000-317APO)
    - Multi Sensor CO and Heat Detector – Bentel Series 600 (Part No. 601CH)
    - Gas Detector – Crowcon Xgard Bright MPS
  - FirePro Condensed Aerosol Fire Protection System.



Item #	Description
1	Box with thermocouples and ballast material
2	Box H860
3	Box H880
4	Box with thermocouples, battery modules and runaway system
5	Container 3250x2650x2420

Figure 1: BESS Test rig



Item #	Description
1	Box with thermocouples and ballast material
2	Box H860
3	Box H880
4	Box with thermocouples, battery modules and runaway system

Figure 2: Typical test rack arrangement.

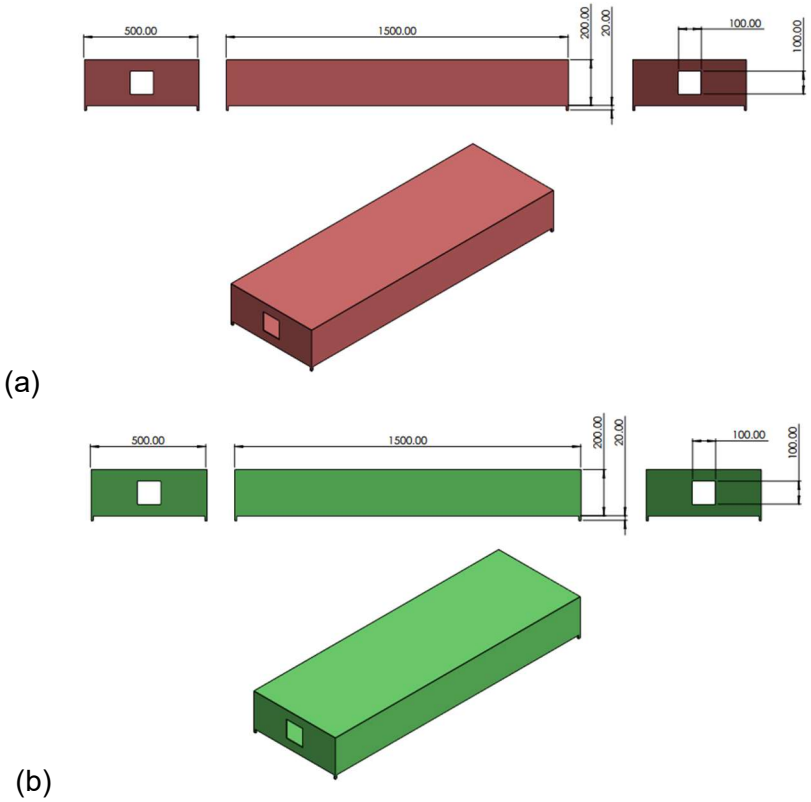


Figure 3: Battery pack configuration; (a) With batteries and thermocouples and (b) With thermocouples and ballast material.

TEST OBJECT:

BESS FITTED WITH LITHIUM POLYMERS BATTERIES

Lithium nickel manganese cobalt oxides (abbreviated NMC, Li-NMC, LNMC, or NCM)

This type of battery is the most offered alternative option by the BESS manufacturers, as their very high performances compared to the basic cheapest choice of LiFePO4 lithium iron phosphate battery (LFP), less performing but less sensitive to a mismanagement.

The NMC batteries are very costly, compared to the cost of LFP batteries; to contain the cost of BESS unit manufacturers are sourcing a “second life LFP batteries” from the automotive market, it will increase the risk of runaway as the “second life LFP batteries” have been already subjected to an intense use, aging and mismanagement.

The battery test object shall be fully charged.

It has been decided to run these tests with Lithium nickel manganese cobalt oxides (abbreviated NMC, Li-NMC, LNMC, or NCM), because, according the public domain literature and recent test, demonstrated to be the most reactive ones.

FIREPRO ENGINEERED SYSTEM

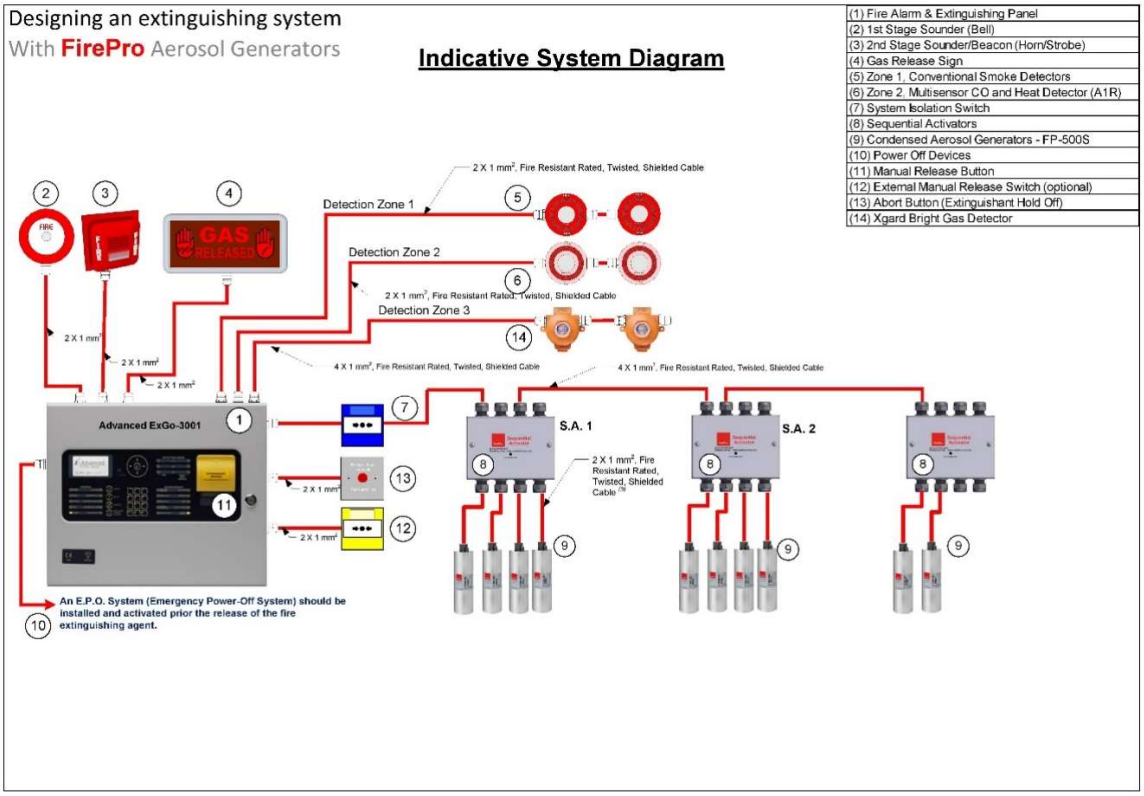


Figure 4: FirePro Engineered System Diagram.

TEST PROCEDURE

TEST PROCEDURE

Inducing the Thermal Runaway

The Thermal Runaway Phenomena of the “real BESS module” will be induced by **overcharging** one “submodule”, with natural propagation to the other ones forming the “real BESS module”.

Previous test demonstrated that a current of 50A will induce the thermal runaway in approx. 30 minutes after starting the overcharging.

WHY “OVERCHARGING”:

Because it will represent the “worst case” raising the amount of energy stored to the dangerous level “never to be reached” (each elementary cell at full charge is 3,8 Volt and reaching the overcharging will reach 4,2 Volt, overheating and initiating the runaway).

THERMAL RUNAWAY

The kinetics of the thermal runaway phenomenon of these cells is known from data derived from previous experimental laboratory tests.
These Lithium Polymer Battery cells represent the worst-case scenario, due to the high amount of gasified electrolyte generated in the event of a thermal runaway (each cell develops about 500 liters of gasified electrolyte).

THERMAL RUNAWAY CONTROL/INTERRUPT

The engineered Condensed Aerosol System by FirePro, including early detection (see Figure 4) will be installed on the test rig and tested to demonstrate his capabilities to control and interrupt a thermal runaway protection a “real BESS”.

PASS-FAIL CRITERIA

It is expected that the “real BESS module” on which thermal runaway was induced will be totally destroyed, the PASS criteria is if the registered temperatures inside the “dummy modules” will be lower than the “critical cell temperature” of 90 C. that is the runaway starting temperature.

GENERAL WARNING

Several previous tests run by the author demonstrated the necessity of special attention to the safety measures, operators shall be specifically trained and the removal of wreckage shall be done by trained personnel.

TEST TO BE PERFORMED

BESS PROTECTION FIRST TEST:

Thermal Runaway Induced by Overcharging Procedure as described above.

FirePro Engineered System including:
Detection System:

- Optical Smoke Detector - Apollo Series 65 (Part No. 55000-317APO)
- Multi Sensor CO and Heat Detector – Bentel Series 600 (Part No. 601CH)
- Gas Detector – Crowcon Xgard Bright MPS
- Detection Control Panel – Advanced ExGo three zone extinguishing panel
- Sequential Actuation System – FirePro Advanced (FP-SEQACT)

Runaway Control/Interruption Agent

- 10 FP-500S Condensed Aerosol Generators protecting the BESS enclosure
- FPC LIION TABS protecting the BESS module fitted with NMC Batteries

Condensed Aerosol design density 173 grams/cubic meter
(includes factor for leakage compensation)

BESS PROTECTION SECOND TEST

Thermal Runaway Induced by Overcharging Procedure as described above.

FirePro Engineered System including:
Detection System:

- Optical Smoke Detector - Apollo Series 65 (Part No. 55000-317APO)
- Multi Sensor CO and Heat Detector – Bentel Series 600 (Part No. 601CH)
- Gas Detector – Crowcon Xgard Bright MPS
- Detection Control Panel – Advanced ExGo three zone extinguishing panel
- Sequential Actuation System – FirePro Advanced (FP-SEQACT)

- 10 FP-500S Condensed Aerosol Generators protecting the BESS enclosure

Condensed Aerosol design density 171 grams/cubic meter
(includes factor for leakage compensation)

IMPORTANT NOTICE

The author Luciano Borghetti, Specialty Engineering and Life Safety Expert, based on statistical information, reports available on public domains and through a specific experimental campaign, has developed this document.

The author made extensive efforts to check the accuracy of the information and advice contained in this document and it is believed to be accurate at the time of issuing.

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Refer to Annex E for Mr. Borghetti's CV

ANNEX A1: FIREPRO DATASHEET OPTICAL SMOKE DETECTOR

DATASHEET - OPTICAL SMOKE DETECTOR - APOLLO SERIES 65

Series 65

Optical Smoke Detector

Product overview

Product	Optical Smoke Detector
Part No.	55000-317
Product	Optical Smoke Detector with flashing LED
Part No.	55000-316
Product	Optical Smoke Detector with magnetic test switch and flashing LED
Part No.	55000-315

Product information

The Series 65 Optical Smoke Detector uses the scattered light principle to 'see' smoke entering the chamber located within the detector housing.

- Responds well to slow burning, smouldering fires
- Well suited for bedrooms and escape routes
- Unaffected by wind or atmospheric pressure
- Flashing LED and magnet operated test switch option on selected detectors

Manufacturer's Specification

All data is supplied subject to change without notice. Specifications are typical at 24 V, 23°C and 50% RH unless otherwise stated.

Detection principle	*Photo-electric detection of light scattered in a forward direction by smoke particles*
Chamber configuration	*Horizontal optical bench housing an infrared emitter and sensor arranged radially to detect scattered light*
Sensor	*Silicon PIN photo-diode*
Emitter	*GaAs infra-red light emitting diode*
Sampling frequency	*Once every three seconds*
Confirmation frequency	*Once every two seconds*
Supply Wiring	*Two wire supply, polarity insensitive*
Terminal functions	*L1 IN* *Supply in connections and L2* *L1 OUT* *Supply out connections and L2* *–R* *Remote indicator negative connection*
Supply voltage	*9 V to 33 V dc*
Ripple voltage	*2 V peak to peak maximum at 0.1 Hz to 100 kHz*
Quiescent current	*30 - 50 µA at 24 V*
Power-up surge current	*115 µA at 24 V*
Alarm voltage	*6 V to 28 V*
Normal alarm current	*61 mA at 28 V* *52 mA at 24 V* *18 mA at 10 V*
Alarm indicator	*Clear light emitting diode (LED) emitting red light*
Alarm LED current	*4 mA*
Remote output characteristics	*Remote is a current sink to the negative line limited to 17 mA*
Sensitivity	*Nominal alarm threshold of 0.15 dB/m obscuration, measured in accordance with EN 54-7*
Operating temperature	*-20°C to + 60°C*
Humidity	*0% to 95% RH (no condensation or icing)*
Effect of atmospheric pressure	*Unaffected*
Effect of wind speed	*Unaffected*
Vibration, impact and shock	*EN 54-7*
Dimensions	*100 mm diameter x 42 mm height*
Weight	*99 g*
Materials	*Housing: White flame-retardant polycarbonate* *Terminals: Nickel plated stainless steel*

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Operating principles

The Series 65 Optical Smoke Detector has a moulded self-extinguishing white polycarbonate case with wind resistant smoke inlets. Inside the case a printed circuit board has the optical system mounted on one side and the signal processing electronics on the other. The sensing chamber is a moulding configured as a labyrinth which prevents penetration of ambient light. The labyrinth has a fine gauze insect-resistant cover. The chamber houses an infrared light emitting diode (LED) and a photo-diode which has an integral visible-light filter as an extra precaution against ambient light.

Every three seconds the LED emits a burst of collimated light, modulated at 4 kHz. In clear air light from the LED does not fall directly on the diode because the LED is positioned at an obtuse angle to the diode.

When smoke enters the chamber a fraction of the collimated light is scattered onto the photo-diode. If the resulting signal from the photo-diode is above a pre-set threshold the LED emits two bursts of light, this time at two-second intervals. If light is scattered onto the photo-diode by both these pulses - due to the presence of smoke - the detector signals an alarm state by switching the alarm latch on increasing the current drawn from the supply from about 40 µA to a maximum of 75 mA. This fall in the impedance of the detector is recognised by the control panel as an alarm signal.

The alarm current also illuminates the detectors integral LED. A remote indicator connected between the L1 IN terminal and the -R terminal will have a voltage equal to the supply voltage less one volt across it and so will illuminate.

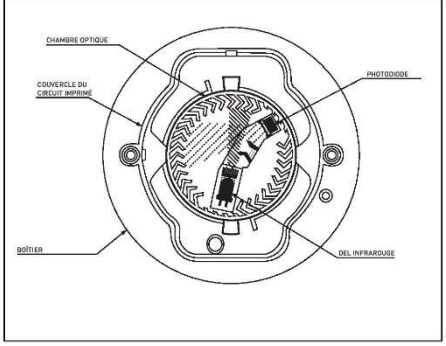
To ensure correct operation of the detector the control panel must be arranged to supply a maximum of 33 V dc and a minimum of 9 V dc in normal operation. The supply may fall to 6 V dc in alarm conditions if a supply current of at least 10 mA is available at this voltage. To ensure effective illumination of the integral LED and any remote indicator the supply to the detector should exceed 12 V.

To restore the detector to quiescent condition it is necessary to expel any smoke and interrupt the electrical supply to the detector for a minimum of one second.

Environmental characteristics

The Optical Smoke Detector is unaffected by wind or atmospheric pressure and operates over the temperature range -20°C to +60°C.

Series 65 Optical Smoke Detector diagram



Response characteristics of Series 65 Optical Smoke Detector

Type of fire	Response
Overheating/thermal combustion	Very Good
Smouldering/glowing combustion	Moderate/Good
Flaming combustion	Very Good
Flaming with high heat output	Very Good
Flaming - clean burning	Poor

EMC Directive 2014/30/EU

The Series 65 Optical Smoke Detector complies with the essential requirements of the EMC Directive 2014/30/EU, provided that it is used as described in this datasheet.

A copy of the Declaration of Conformity is available from Apollo upon request.

Conformity of the Series 65 Optical Smoke detector with the EMC Directive does not confer compliance with the directive on any apparatus or systems connected to it.

Construction Products Regulation (EU) 305/2011

The Series 65 Optical Smoke Detector complies with the essential requirements of the Construction Products Regulation (EU) 305/2011.

A copy of the Declaration of Performance is available from Apollo upon request.

apollo

ANNEX A2: FIREPRO DATASHEET CO & HEAT DETECTOR

DATASHEET - MULTI SENSOR CO AND HEAT DETECTOR – BENTEL SERIES 600

Serie 600

SERIE 600

Il costante impegno nella ricerca e sviluppo nel settore della rilevazione di incendio ha permesso la realizzazione della nuova serie 600 di rilevatori convenzionali, eleganti e discreti nel design, progettati per offrire una sempre maggiore affidabilità e velocità di risposta, facili da installare e con un bassissimo bisogno di manutenzioni.
La serie 600 include il rilevatore di monossido di carbonio ad elevate prestazioni (601CH) il quale, grazie alla cella elettrochimica per la rilevazione del CO ed ai sensori di temperatura di cui è dotato, garantisce un riconoscimento rapido ed affidabile sia dei principi di incendio a combustione lenta sia di quelli veloci.

L'intera gamma dei rilevatori è conforme alle normative europee (EN54) in materia di rilevatori di incendio oltre che a tutti quei requisiti previsti dalla marchiatura CE.

- Approvazione EN54 da LPCB
- Tensione di funzionamento da 10,5Vdc a 33Vdc
- Design piacevole e discreto
- Elevate prestazioni ed affidabilità
- Facili da installare
- LED di segnalazione allarme integrato
- Possibilità di collegamento di un LED remoto
- Collegamento indipendente dalle polarità
- Compatibile con la base standard e la base relè

I rilevatori convenzionali o rilevatori a due stati della serie 600, forniscono due stati di uscita: riposo o allarme. Abbinati alle opportune apparecchiature di controllo e segnalazione vanno a costituire il sistema di rilevazione automatico di incendio.

APPLICAZIONI

Ciascun tipo di rilevatore è in grado di riconoscere un particolare prodotto della combustione, le relative velocità di risposta sono quindi dipendenti dal tipo di elemento preso in considerazione dal rilevatore stesso. La gamma dei rilevatori serie 600 è stata progettata per garantire la massima velocità di risposta nel riconoscimento dei principi di incendio con la minima possibilità di falsi allarmi.
Il fumo è generalmente presente nei primi stadi della maggior parte degli incendi, i rilevatori di fumo (Ottici ed Ottici ad alte prestazioni) sono quindi considerati i più adeguati nella maggior parte dei casi. Nella scelta del tipo di rilevatore di fumo bisogna tenere conto del tipo di combustibile che potrebbe alimentare un eventuale incendio; in generale i rilevatori ottici (601P) sono maggiormente indicati per quelle applicazioni dove esiste un rischio di sviluppo di incendio lento, causato da surriscaldamento di materiali infiammabili mentre i rilevatori ottici ad alte prestazioni (601PH) offrono una eccellente soluzione per quelle situazioni dove coesiste la possibilità di un incendio a combustione lenta o veloce con repentino sviluppo di fiamme.

I rilevatori di temperatura (a temperatura fissa o termovelocimetrici 601H-F/601H-R) e quelli di monossido di carbonio (601CH) vanno utilizzati in quelle applicazioni dove l'installazione di rilevatori di fumo produrrebbero una quantità inaccettabile di falsi allarmi.

Considerata la grande varietà di applicazioni che i rilevatori di incendio sono chiamati a coprire si raccomanda una stima accurata ed approfondita dei rischi di incendio al fine di determinare il tipo di sensore più adeguato per ogni singola applicazione.

SERIES 600

Conventional detector design evolution has resulted in the creation of a new Series 600 range of unobtrusively styled detectors, incorporating a number of unique design features enabling improved operation, installation and ease of servicing. Included within the Series 600 range is the new conventional enhanced carbon monoxide fire detector (601CH).
The incorporation of a reliable electrochemical CO detection cell and high specification low thermal mass thermistor for accurate temperature detection has enabled the introduction of an enhanced CO detector suitable for fast, reliable detection on both slow and fast developing fires. The complete range has been designed to meet the requirements of the EN (European Standards) for fire detectors.

All detectors also carry a mandatory CE mark.

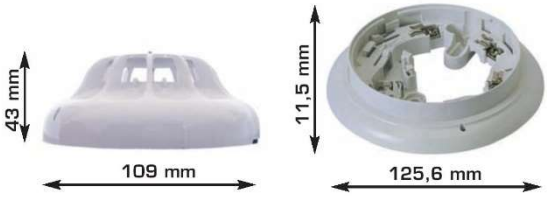
- *EN54 approved by LPCB*
- *Low operational voltage : 10.5V to 33V*
- *Aesthetically discreet*
- *Superior performance and reliability*
- *Designed for rapid installation*
- *Integrated alarm led*
- *Remote led connection*
- *Wiring polarity independent*
- *Compatible with standard mounting base and with relay base*

APPLICATION

As each type of fire detector responds to a particular "fire characteristic", the relative speed of response of the detector is therefore dependent upon the type of fire being detected. The range of Series 600 fire detectors have been designed to provide the earliest possible warning of a fire condition, with a minimum possibility of false/unwanted alarms.
As smoke is normally present at an early stage in most fires, smoke detectors (optical or high performance optical) are therefore considered the most useful. When considering the type of smoke detector for the application, the probable type of fuel for the fire should be considered, in general terms, optycal type smoke detector (601P) are suitable for slow developing fire, whereas where there is an equal possibility of either a "fast" or "slow" fire developing the intelligent high performance optical detector (601PH) provides an excellent detection response.

In situations where the installation of smoke detectors would cause an unacceptable level of false alarms, heat detectors or the enhanced CO fire detectors may be installed.

Because of the wide variety of applications that fire detectors are expected to cover, it should be undertaken to determine the most suitable detector for any application.



	SPECIFICHE *SPECIFICATION*	PESO (Kg) *WEIGHT (Kg)*	TENSIONE DI ALIMENTAZIONE (Vdc) *SUPPLY VOLTAGE (Vdc)*	ASSORBIMENTO MEDIO IN STAND BY (uA) *AVERAGE QUIESCENT CURRENT (uA)*		ASSORBIMENTO IN ALLARME (mA) *ALARM CURRENT (mA)*		TEMPERATURE DI FUNZIONAMENTO (NO CONDENSA O GHIACCIO) *OPERATING TEMPERATURE (NO CONDENSATION OR ICING)*	TEMPERATURE DI IMMAGAZINAMENTO (NO CONDENSA O GHIACCIO) *STORAGE TEMPERATURE (NO CONDENSATION OR ICING)*	CORRENTE PER REMOTO (Ave) A 24V (RESISTENZA DA 1K1 INTERNA) *REMOTE LED CURRENT (mA) @ 24V (1K1 INTERNAL RESISTOR FITTED)*	APPROVAZIONI *APPROVAL*
TIPO - *TYPE*	DESCRIZIONE - *DESCRIPTION*	10,5V	24V	10,5V	24V	10,5V	24V				
601P	FUMO - OTTICO *OPTICAL SMOKE*	0,093	10,5 - 33	63	67	12	45	-20°C.. +70°C	-25°C.. +80°C	21	LPCB
601PH	FUMO – OTTICO AD ALTE PRESTAZIONI *HIGHT PERFORMANCE OPTICAL SMOKE*	0,093	10,5 - 33	63	67	12	45	-20°C.. +70°C	-25°C.. +80°C	21	LPCB
601H-R	TEMPERATURA - TERMOVELOCIMETRICO *HEAT RATE OF RISE*	0,08	10,5 - 33	57	65	14	35	-20°C.. +70°C	-25°C.. +80°C	21	LPCB
601H-F	TEMPERATURA – SOGLIA FISSA A 60°C *HEAT 60° C FIXED TEMP*	0,08	10,5 - 33	58	61	14	53	-20°C.. +70°C	-25°C.. +80°C	21	LPCB
601CH	MONOSSIDO DI CARBONIO *ENHANCED CO FIRE*	0,09	10,5 - 33	60	68	60	53	-10°C.. +55°C	-10°C.. +55°C	21	LPCB
5B	BASE UNIVERSALE *UNIVERSAL BASE*	0,065	-	-	-	-	-			-	LPCB
MUB-RV	BASE UNIVERSALE CON RELÈ *UNIVERSAL RELAY BASE*	0,066	10,5 - 33	-	-	15	12	-10°C.. +55°C	-20°C.. +55°C	-	LPCB

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Series 600

601P

Il rilevatore 601P è in grado di rilevare il fumo visibile prodotto da materiali che bruciano senza fiamma o con combustione lenta (mobili, materie plastiche espanse, PVC surriscaldato).

Il rilevatore 601P è particolarmente indicato per applicazioni di tipo generale e per aree dove potrebbe verificarsi un surriscaldamento di cavi. Il rilevatore di fumo ottico non è indicato per il rilevamento di incendi a combustione veloce i quali producono del fumo scarsamente visibile o fumo particolarmente scuro. L'originale disegno della camera di rilevamento e la tecnica di analisi dei segnali evita le segnalazioni di falsi allarmi causati da piccoli insetti. Il fumo che penetra nella camera di campionamento riflette degli impulsi di luce infrarossa verso un ricevitore che li converte in segnali elettrici. Dei circuiti interni provvedono a valutare tali segnali elettrici al fine di discriminare una eventuale condizione di allarme.

601P

601P detectors are capable of detecting the visible smoke produced by materials which smoulder or burn slowly, i.e. soft furnishings, plastic foam etc; or smoke produced by overheated but unburnt PVC.

These detectors are particularly suitable for general applications and areas. Optical only detectors are not suitable for detecting fast burning fires producing little visible smoke or very black smoke. The novel design of the asymmetrical sampling chamber and signal processing techniques stop unwanted alarms caused by very small insects, i.e. thrips. Smoke entering the sampling chamber scatters the infra-red light pulses onto a photodiode. These pulses are converted to an electrical signal which is compared against a preset alarm level.

601PH

Il rilevatore 601PH è in grado di rilevare una vasta gamma di prodotti della combustione, da quelli generati da principi di incendio lenti e senza fiamma che producono delle particelle visibili fino a quelli con fiamme vive che producono un gran numero di particelle caldissime e di più piccole dimensioni.

La combinazione del principio ottico e termico permette la rilevazione di quei focolai con fiamme vive che fino ad ora potevano essere rilevati soltanto per mezzo di rilevatori a ionizzazione. Nelle normali condizioni ambientali il 601PH si comporta come un normale rilevatore di fumo ottico, soltanto nel caso in cui venga rilevato un rapido innalzamento della temperatura il rilevatore aumenta la sua sensibilità e l'eventuale presenza di fumo conferma la condizione di incendio che attiverà la trasmissione dell'allarme al dispositivo di controllo. Il rilevatore 601PH è dotato di una camera di rilevamento ottica disegnata in modo da ottenere un rapporto segnale - rumore senza rivali e una elevata immunità alla polvere ed allo sporco che garantisce una sensibile riduzione dei costi di manutenzione. Inoltre la copertura della suddetta camera è stata studiata per richiamare all'interno della stessa il fumo in condizioni di scarsa mobilità dell'aria rendendo il rilevatore più rapido nella sua risposta.

601PH

601PH detectors react to the complete range of fire products, from slow smoldering fires, producing visible particles to open flaming fires producing large numbers of very hot smaller sized aerosols.

The combination of optical and heat technology allows detection of clear burning fire products which hitherto could only be easily detected by ion-chamber detectors. For normal ambient conditions the HPD behaves as a normal detector. Only when a rapid rise in temperature is detected does the sensitivity of the detector increase and the presence of smoke will confirm a fire condition which will be trasmitted as an alarm level. The 601PH design incorporates a unique "mousehole" optical chamber whith an unrivaled signal to noise ratio providing high resilience to dust and dirt which means reduced servicing cost. In addition a unique chamber cover actually draws slow moving smoke into the chamber to provide a more responsive detector.

601H-R / 601H-F

I rilevatori 601H-R (termovelocimetrico) e 601H-F (temperatura fissa) rilevano rispettivamente un anormale rapido innalzamento della temperatura e un anormale elevato livello di temperatura.

Nelle normali applicazioni ed in particolar modo in quei casi dove le temperature sono particolarmente basse è preferibile l'utilizzo del rilevatore termovelocimetrico 601H-R. Tali rilevatori sono comunque provvisti di una soglia fissa. In alcuni ambienti quali cucine, locali caldaie, rapidi innalzamenti della temperatura sono considerati normali, l'utilizzo in questi ambienti di rilevatori termovelocimetrici è pertanto inadeguato ed è preferibile utilizzare un rilevatore a temperatura fissa 601H-F.

601H-R / 601H-F

Heat detectors offer an acceptable, but less sensitive alternative to smoke detectors if environmental conditions rule out their use.

601H-R (rate of rise) and 601H-F (fixed temperature) detectors detect abnormally high rates of rise of temperature and abnormally high (static) temperatures respectively. For general use and particular where the ambient temperature may be low, a rate of rise heat detector 601H-R is to be preferred. A fixed temperature limit is also incorporated in these detectors. In many environments, e.g. kitchens, canteens and boiler rooms, sudden large changes in temperature are considered normal therefore rate-of-rise detectors are generally not suitable in these cases and a slower response fixed temperature detector 601H-F should be used.

601CH

Il 601CH è caratterizzato da una elevata velocità di risposta nella rilevazione dei principi di incendio, da una elevata flessibilità di installazione che ne permette l'utilizzo in quelle applicazioni dove ostacoli impedirebbero la libera circolazione dell'eventuale fumo.

Il rilevatore è particolarmente indicato per quelle zone ad elevato rischio, aree di immagazzinamento e tutte quelle situazioni nelle quali un rilevatore di fumo tenderebbe a dare falsi allarmi. Il rilevatore termovelocimetrico A1R incorporato nel rilevatore fornisce un ulteriore non escludibile fonte di rilevazione che permette al rilevatore di risultare adeguato anche in quelle applicazioni dove la presenza di rischi combinati porterebbe la sola rilevazione di CO ad essere insufficiente. Il rilevatore termovelocimetrico incorporato si comporta come un normale rilevatore termico, inoltre, in caso di rilevamento di un repentino innalzamento della temperatura, forza un aumento della sensibilità del rilevatore di monossido di carbonio.

601CH

601CH detectors are generally faster than optical detectors in responding to fires that start by smoldering. they are also more tolerant of positioning and can be mounted in locations where there are likely to be obstacles to free smoke plume movement.

These detectors are particularly well suited to sleeping risk, storage areas and applications where smoke detectors are prone to false alarm. Incorporation of A1R rate of rise heat detector within the 601CH provides extra non-selectable detection modes which allows the detector to operate in a wide variety of applications where combined risk mean that CO detection alone would be insufficient. The integrated rate-of-rise heat detector acts as a normal heat detector, additionally anhancing the sensitivity of the carbon monoxide detector if a rapid change of temperature is detected by the detectors thermistor.

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Rilevatori di Incendio Convenzionali - *Conventional Fire Detectors*

SERIE 600

AREE APPLICATIVE SERIE 600 - *SERIES 600 APPLICATION NOTES*

AMBIENTE *ENVIROMENT*		MOLTO PULITO E SECCO *CLEAN AND DRY*	MODERATAMENTE PULITO E TEMPERATURA MODERATA *MODERATLY CLEAN REGULATED TEMPERATURE*	SPORCO FUMOSO *DIRTY SMOKY*	SPORCO E/O UMIDO *DUSTY AND /OR HUMID*	CALDO FUMOSO *HOT AND SMOKY*	ARIA APERTA *OPEN AREAS*
MATERIALI *FIRE LOADING*	**PROBABILI RISCHI** *PROBABLE RISK*	Camere pulite centro elaborazione dati *Clean room Data processing suite*	Uffici industrie leggere ospedali, residenziale, sale d'aspetto *Offices, light industrial, hospitals, residential, passenger accomodation*	Zone di carico merci,magazzini con muletti diesel, industrie pesanti, autofficine *Loading bay/warehouse with diesel fork-lifts etc. Heavy industrial Ferry (car deck)*	Allevamenti bestiame, lavanderie spogliatoi *Livestock pen mill, laundry, chancing room*	Cucine sale macchina *Kitchen engine room engine test beds*	
Apparecchiature elettroniche - motori elettrici - cavi elettrici *Electronic equipment - Electrical switchgear - Electric motors - Cable conduit*	**Principi lenti senza fiamma, nascosti (difficili da localizzare -fumi tossici)** *Cable pyrolysis (toxic fumes) Electrical arcs (ignition source) Associated electrical dangers*	601P 601H	601P 601HP	601P			
Stoffe, vestiti - Mobili - Carte e cartoni Materie plastiche Locali destinati ad animali Segatura, scarti di legnami *Fabrics, clothes soft furnishings - paper - cardboard plastic foams - Animal bedding, wood shavings*	**Principi lenti senza fiamma, nascosti (difficili da localizzare-fumi tossici)** *Smoulderings (difficult to locate – toxic fumes) like hood of flashover back draught)*	601H 601H 601P	601CH 601P	601CH 601P	601CH	601CH	
Liquidi infiammabili Vernici - solventi gas infiammabili Sostanze chimiche instabili *Flammable liquids - Paints - Solvents - Flammable gasses - Unstable chemicals*	**Fiamme (rapida crescita di fumo denso) Fumi ad alta temperatura rischi di esplosioni associate** *Flaming fire (rapid build up of dense smoke) High temperature fumes Associated explosion dangers*	601H 601P	601PH 601HP			601HR	
Generi alimentari Rifiuti organici foraggio per animale Strutture in legno Combustibili solidi *FoodStuffs General organic waste animal feed Wooden structures Solid fuels*	**Fumo e fiamme inizialmente piuttosto lento ma una volta innescato l'incendio alta temperature** *Smoke and Flame Initially fairly slow but high temperature once estabilished*	601H	601H 601P 601CH	601CH 601CH 601H	601H-R 601P 601H-R	601CH 601CH	
Prodotti plastici, prodotti chimici Macchine utensili - Materiali da costruzione Contenuti non conosciuti *Plastic chemicals Machinery - Building materials Unknown contents*	**I tipi di rischio possono variare a seconda del tipo di incendio (potrebbe essere necessario l'utilizzo di più di un tipo di rilevazione)** *Type of fire risk may vary as can the type of fire (may require a mix of detection types)*	601H 601CH 601P	601PH 601CH 601PH-R	601P 601CH	601CH 601P	601H-R 601CH	601CH

SPECIFICHE TECNICHE - *TECHNICAL SPECIFICATION*

MECCANICHE - *MECHANICAL*	
Materiale - *Detector Material*	FR110 "Bayblend" resistente al fuoco - *FR110 "Bayblend" fire resistant*
Dimensioni - *Dimensions*	Vedi figura 1 - *See figure 1*
Peso - *Weight*	Vedi Tabella - *See specification summary*
Colore - *Color*	Bianco - *White*
ELETTRICHE - *ELECTRICAL*	
Tempo di reset - *Reset Time*	2 – 5 secondi - *2 - 5 seconds*
Umidità relativa - *Relative Humidity*	0 – 95% non condensing
Connessione cavi - *Wiring Connections*	Sulla Base - terminali a vite - Max 2x1,5 mm^2 per ogni terminale - *On MUB - Max 2x1,5 mm^2 each terminal*
CONFORMITÀ - *CONFORMS WITH:*	
EN 54-5:2000 + A1:2002	Sistemi di rilevazione e di segnalazione d'incendio - Rilevatori di calore - Rilevatori puntiformi *Fire detection and fire alarm systems - Heat detectors - Point detectors*
EN 54-7:2000 + A1:2002	Sistemi di rilevazione e di segnalazione d'incendio - Rilevatori di fumo - Rilevatori puntiformi funzionanti secondo il principio della diffusione della luce, della trasmissione della luce o della ionizzazione. *Fire detection and fire alarm systems - Smoke detectors - Point detectors using scattered light, transmitted light or ionization*

Distributed by:

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ANNEX A3: FIREPRO DATASHEET GAS DETECTOR

DATASHEET - GAS DETECTOR – CROWCON XGARD BRIGHT MPS

Xgard Bright MPS™

Meet the next generation of flammable gas detection

Crowcon has introduced the first molecular property spectrometer (MPS™) flammable gas sensor for a fixed gas detector. Crowcon's Xgard Bright with Nevada Nanotech MPS™ sensor provides advanced technology that removes the need to calibrate and provides a 'True LEL™' reading for all flammable gases in a multi-species environment, resulting in lower ongoing maintenance costs and reduced interaction with the unit.

This reduces risk to personnel, and avoids costly downtime. The MPS™ sensor is also immune to sensor poisoning.

The MPS™ sensor delivers key features which provide real world tangible benefits to operator and site operations.

No calibration:	The Xgard Bright with MPS™ sensor technology does not require calibration. This in turn reduces the interaction with the detector resulting in a lower total cost of ownership over the sensor life cycle, and reduces risk to personnel and production output to complete regular maintenance.
Multi-species True LEL™:	The Xgard Bright with MPS™ sensor can accurately detect multiple flammable gases at once. The MPS™ sensor has an on board environmental compensation and does not require a correctional factor. Inaccurate readings and false alarms are now a thing of the past.
No sensor poisoning:	The Xgard Bright with MPS™ sensor cannot be poisoned. Sensor failure due to poisoning can be a frustrating and costly experience. The technology in the MPS™ sensor is not affected by contaminates in the environment. Processes that have contaminates now have access to a solution that operates reliably with fail safe design to alert the operator to offer peace of mind for personnel and assets located in hazardous environments.
Hydrogen detection:	The Xgard Bright with MPS™ sensor provides a far better solution for Hydrogen detection. The challenges faced with traditional sensor technology are completely removed. A long life hydrogen sensor that does not require calibration throughout the life cycle of the sensor, without the risk of poisoning or false alarms can significantly save on total cost of ownership and reduces interaction with unit resulting in peace of mind and reduced risk for operators leveraging MPS™ technology.

CROWCON
Detecting Gas Saving Lives

TrueLEL™ Multi-gas accuracy

The Xgard Bright with MPS TrueLEL™ sensor can accurately detect multiple flammable gases using the same sensor without any correctional factors

Single factory calibration:	One factory calibration to Methane delivers accuracy across 15 common flammable gases including hydrogen.
Automated environmental compensation:	Built in compensation for temperature, pressure, and humidity. Gas concentration readings are accurate across the full environmental range.
No maintenance:	The Xgard Bright with MPS™ sensor doesn't drift, decay, or poison and requires no maintenance over its lifetime

Existing technology is typically calibrated to a single flammable species, meaning that all other species will be incorrectly monitored. This means you will experience false and masked alarms.

The MPS™ sensor has TrueLEL™ multi-gas accuracy, detecting 15 different flammable gases from a single sensor.

Crowcon helps your business improves operational efficiency, giving confidence in your gas detection system.

Gas	Formula	Detection Range	Accuracy (at 50% LEL)
butane	C_4H_{10}	0-100 % LEL	±5% LEL
ethane	C_2H_6	0-100 % LEL	±5% LEL
hexane	C_6H_{14}	0-100 % LEL	±8% LEL
hydrogen	H_2	0-100 % LEL	±5% LEL
isobutane	$HC(CH_3)_3$	0-100 % LEL	±5% LEL
isobutylene	C_4H_8	0-100 % LEL	±5% LEL
isopropanol	C_3H_8O	0-100 % LEL	±10% LEL
methane	**CH_4**	**0-100 % LEL**	**±3% LEL**
methyl ethyl ketone	C_4H_8O	0-100 % LEL	±5% LEL
octane	C_8H_{18}	0-100 % LEL	±5% LEL
pentane	C_5H_{12}	0-100 % LEL	±5% LEL
propane	C_3H_8	0-100 % LEL	±5% LEL
propylene	C_3H_6	0-100 % LEL	±5% LEL
toluene	C_7H_8	0-100 % LEL	±10% LEL
xylene	C_8H_{10}	0-100 % LEL	±10% LEL

Accuracy guaranteed for methane across full environmental range

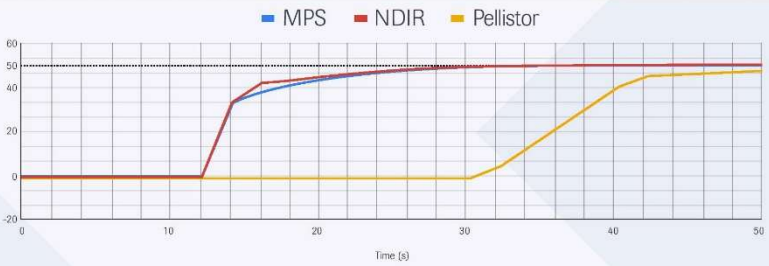
1st February 2021

TrueLEL™ Multi-gas accuracy

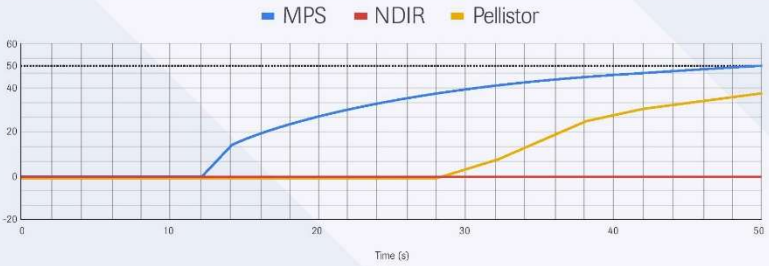
Flammable gases are prevalent in multiple industries such as energy, wastewater, petrochemical, oil, gas, and industrial manufacturing.

There are challenges with traditional sensor technology in environments with multiple flammable gases present. The below graphs demonstrate the response of 3 sensor technology types which all have been factory calibrated to Methane (CH^4) 50% LEL.

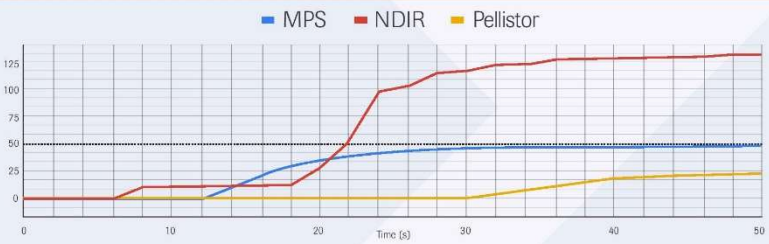
Methane



Hydrogen



Butane



All 3 sensor types will react with the same output delivering an accurate reading for Methane (CH^4).

But replicating a multi species gas environment where an alternative flammable gas is exposed to the same detector with the same sensor a different reading is detected.

Traditional sensor technology when exposed to a non target gas will provide an inaccurate reading. When applying different flammable gas concentrations of Butane 50% LEL & Hydrogen 50% LEL the results captured display over readings, and under readings of gas levels. The detector will respond to inaccurate over readings and under readings with false alarms or masked due to the inability to accurately detect multiple flammable gases.

The only sensor option that will provide accurate TrueLEL™ readings across 15 flammable gas species is the MPS™ sensor.

Industry spotlight

	No calibration	No poisoning	Multi-species (True LEL™)	Hydrogen (H^2) detection
Waste water	●	●	●	
Waste to energy	●	●		
Chemical	●	●	●	
Biogas	●		●	
Petrochemical	●	●	●	
Downstream	●		●	
Power				●
Upstream	●			
Midstream	●			
Gas distribution	●			
Boiler rooms	●			
Automotive		●		
Steel				●
Blue green energy				●

Keep people and premises safer, with more efficient and accurate monitoring

Application suitability Multiple industry and applications will greatly benefit from the key features that MPSTM technology delivers

Wastewater processing generates multiple gas hazards and requires end-to-end gas monitoring to keep people and property safe.

Existing flammable gas sensor solutions can only monitor a single target gas accurately resulting in multiple detectors required for detecting different flammable gas.

Chemical, petrochemical, Oil & gas downstream processes all face the burden of calibration which entails an ongoing cost and regular disruption by visit of an engineer to complete. A solution that requires a single factory calibration will drastically reduce ongoing calibrations costs and disruption.

Multiple industries suffer from poisoned sensors which is caused by inhibitors or poisons in the environment. Existing sensor technology suffers poisoning from commonly used compounds such as sealant which contain silicon. Even environments with H^2S present such as waste to energy power stations could face challenges due to exposure to H^2S which can reduce existing technology effectiveness to monitor target flammable gas by up to 90% in just a few minutes.

There are various industry and application highlights that would benefit from MPS™ technology – **Biogas / Power stations / Oil & Gas upstream / Oil & Gas midstream / Boiler rooms / Automotive / Steel & Blue Green energy plants (Hydrogen)**.

Wastewater

Wastewater processing generates multiple gas hazards and requires end-to-end gas monitoring to keep people and property safe. Industry needing to monitor flammable gashave had to select either a traditional flame sensor detector with a pellistor calibrated for a specific gas (and multiple pellistors in multi-species environments), or an improved capability sensor using infra-red (IR) which also requires a separate sensor to be calibrated for each gas.

The Xgard Bright with MPS™ sensor ability to detect multiple flammable gases and gas mixtures quickly, accurately and simultaneously is an advantage in environments with multiple, fluctuating, gas hazards.

Green Energy

Demand for hydrogen is growing. Not only is it used as a feedstock for industry, it is also increasingly popular as a zero-emissions fuel for buildings and vehicles and as a means of storing energy from renewable and other green sources. IR detectors cannot identify hydrogen, which until recently has left pellistor technology as the only option. However, pellistors are vulnerable to poisoning. Thus, they require constant maintenance and, in some conditions, frequent replacement.

The Xgard Bright with MPS™ sensor provides a far better solution for Hydrogen detection. The challenges faced with traditional sensor technology are completely removed. A long life hydrogen sensor that does not require calibration throughout the life cycle of the sensor, without the risk of poisoning or false alarms can significantly save on total cost of ownership.

MPS™

1st February 2021

Specification

Enclosure material	ADC 12 aluminium alloy
Dimensions	156 x 166 x 109mm (6.1 x 6.5 x 4.3inch)
Weight	Aluminium alloy 1kg (2.2lbs)
Ingress protection	IP65 & IP66 (with weatherproof cap)
Cable entry	2x M20 (stopping plug fitted to left-side entry) or supplied with ½" NPT adapters
Power	10-30Vdc. 3W max
Electrical output	4-20mA current sink or source RS-485 Modbus RTU HART (optional)
Relays	Alarm 1, Alarm 2, Fault SPST contacts rated 1A 30Vdc
Sounder out	24Vdc (nominally), 250mA maximum load
Operating temperature	-40°C to +70°C (-40°F to 158°F) Note: sensor operating temperatures vary widely Refer to the sensor module datasheet or contact Crowcon for specific sensor data.
Humidity	0 to 95% RH, non-condensing
Approval codes	ATEX and IECEx Ex II 2G Ex db IIC T6 Gb Ex II 2D Ex tb IIIC T80°C Db Certificate numbers: TUV 16 ATEX 7908 X IECEx TUR 16.0035 X
Standards	EN60079-0:2012 + A11:2013 EN60079-1:2014 EN60079-31:2014 IEC60079-0:2017 Edition 7 IEC60079-1:2014-06 IEC60079-31:2013
Zones	Certified for use in Zone 1 and Zone 2 areas
EMC compliance	EN50270:2015
Response time	T90 < 25 seconds*
Expected life span	5 years +
Warranty	4 years
Sensor technology	MPS™

*Dependent on gas type. Number shown based on Methane 100% LEL

Disclaimer

Every effort has been made to ensure the accuracy of this document at the time of printing. In accordance with the company's policy of continued product improvement Crowcon Detection Instruments Limited reserves the right to make product changes without notice. The products are routinely subject to a programme of testing which may result in some changes in the characteristics quoted. Technical information contained in this document or otherwise provided by Crowcon are based upon records, tests, or experience that the company believes to be reliable, but the accuracy, completeness, and representative nature of such information is not guaranteed.

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As the products may be used by the client in circumstances beyond the knowledge and control of Crowcon Detection Instruments Limited, we cannot determine the relevance of these to an individual customer's application. It is the clients' sole responsibility to carry out the necessary tests to evaluate the usefulness of the products and review all applicable regulations and standards to ensure their safety of operation in a particular application.

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Crowcon reserves the right to change the design or specification of the product without notice.

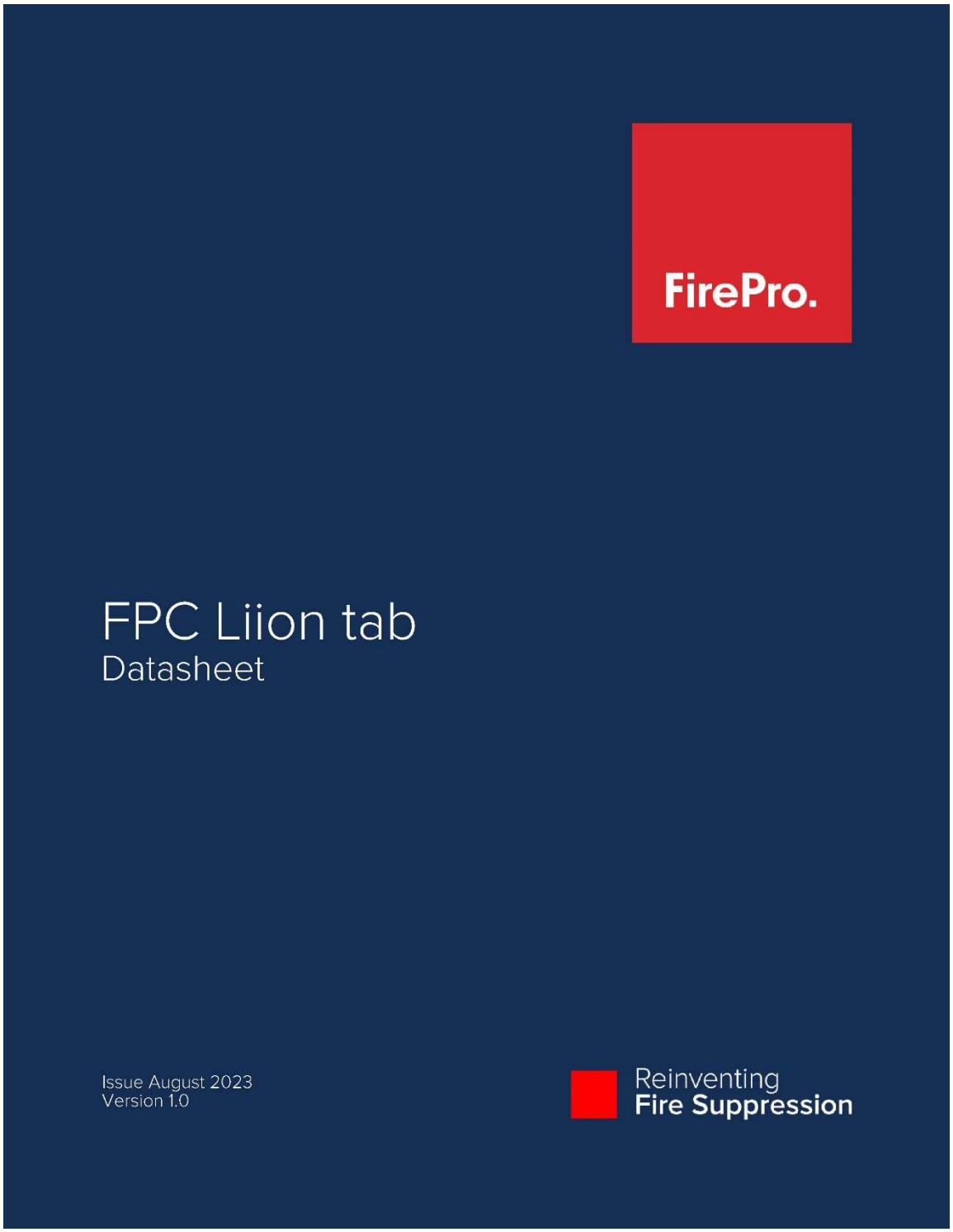
ANNEX B: FIREPRO DATASHEET GENERATOR

FP-500S DATASHEET

FP-500S

TECHNICAL INFORMATION	
Model	FP-500S
Activation mechanism	thermal activation electrical (min.1.5V DC,min 0.8A in 3-4 sec)
Activator type	heating element with 2.3 ohm resistance
Activ. line supervision current	maximum 5 mA
Weight gross	3340 g
Mass of FPC Compound	500 g
Operational discharge time	5 - 10 seconds
Discharge outlet	1
Discharge length	3.0 m
Size	295 mm x 84 mm (incl. connector housing)
Self activation temperature	300 °C
Fire class	A, B, C, F
APPLICATIONS	
Rooms Transport Storage Large switch rooms Cabinets Transformers (large)	False ceilings, Raised floors car, lorry, bus, train, metro, tram cupboards, safes meter cupboards, control units electrical cabinets industry Certified according to: • EN 15276-1 • BRL 23001 • ISO 15779 • UL2775

ANNEX C: FIREPRO DATASHEET LIION TABLETS



Properties

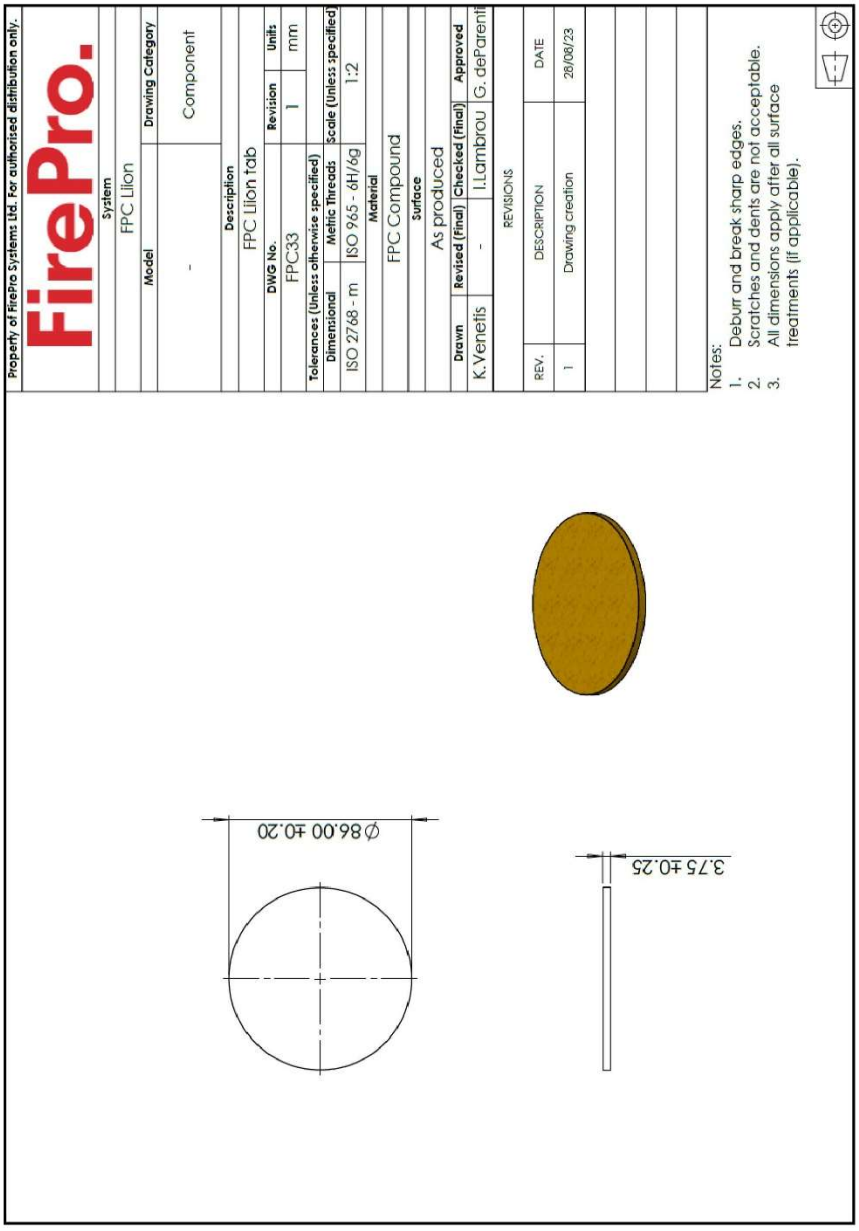
Compound nominal mass	33.5g ± 1.0g
Thickness	3.75mm ± 0.25mm
Diameter	86mm ± 0.2mm
Self-activation Temperature	≥ 300 °C

Features

- Easy installation.
- Light and compact design.
- Polymeric insulation for improved protection. (Optional)
- Enhanced mechanical protection with the use of metal shielding. (Optional)

Health and Safety Guidelines

- Personal Protective Equipment (PPE) must always be worn when handling the FPC tablets.
- The FPC Liion tabs are flammable solids and should always be stored away from heat sources that may lead to accidental activation/discharge.
- Upon activation, the FPC Liion tabs release hot aerosol. Safety distances should be maintained between the activated tablets and flammable materials or personnel.
- Condensed aerosol in a sealed enclosure will lead to increased pressure.
- The discharged condensed aerosol and fire byproducts should always be vented out before personnel is allowed access to the protected enclosure.
- The installation of the FPC Liion tabs should never interfere with the proper operation of the protected equipment.
- Always refer to the Safety Data Sheet before handling the FPC Liion tabs.


Property of FirePro Systems Ltd. For authorized distribution only.
FirePro.
System
FPC Lilon
Model
-
Drawing Category
Component
Description
FPC Lilon tab
DWG No.
FPC33
Revision
1
Units
mm
Tolerances (Unless otherwise specified)
Dimensional
ISO 2768 - m
Metric Threads
ISO 965 - 6H/6g
Scale (Unless specified)
1:2
Material
FPC Compound
Surface
As produced
Drawn
K.Venetis
Revised (final)
-
Checked (final)
I.Lambrou
Approved
G. deParenti
REVISIONS
REV.
DESCRIPTION
DATE
1
Drawing creation
28/08/23
Notes:
1. Deburr and break sharp edges.
2. Scratches and dents are not acceptable.
3. All dimensions apply after all surface treatments (if applicable).
Ø86.00 ±0.20
3.75 ±0.25

Page **3** of **3**

FPC LIION PRODUCT DESCRIPTION

FirePro Liion tab is an advanced formulation of the original FirePro compound (FPC) in tablet form (patent pending), developed for the protection of thermal runaway events in Li-ion batteries. The tablet can be installed directly into the Li-ion battery packs, or between the Li-ion battery modules. In the event of a Li-Ion battery fire, the released FirePro active agent consisting of potassium salts (K_2CO_3) neutralizes the electrolyte`s decomposition products, such as Hydrogen Fluoride (HF), forming stable products (KF, 2KHF). Thus, preventing the formation of highly flammable gases such as Hydrogen (H_2). The resulting neutralizing action controls the fire and allows the temperature in the protected enclosure to drop below the threshold necessary for the thermal runaway to sustain itself.

Features

- Easy installation.
- Light and compact design.
- Self-activation at T ≥ 300 °C.
- Active compound nominal weight: 34 grams
- Dimensions: Ø86 mm x 4 mm
- Polymeric insulation for improved protection.
- Enhanced mechanical protection with the use of metal shielding (Optional).

Health and Safety Guidelines

- Personal Protective Equipment (PPE) must always be worn when handling the FPC tablets.
- The FPC Liion tabs are flammable solids and should always be stored away from heat sources that may lead to accidental activation/discharge.
- Upon activation, the FPC Liion tabs release hot aerosol. Safety distances should be maintained between the activated tablets and flammable materials or personnel.
- Condensed aerosol in a sealed enclosure will lead to increased pressure.
- The discharged condensed aerosol and fire byproducts should always be vented out before personnel is allowed access to the protected enclosure.
- The installation of the FPC Liion tabs should never interfere with the proper operation of the protected equipment.
- Always refer to the Safety Data Sheet before handling the FPC Liion tabs.

ANNEX D: FIREPRO PATENT

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 925 808 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
27.08.2003 Bulletin 2003/35

(21) Application number: **97915780.7**

(22) Date of filing: **14.03.1997**

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(86) International application number:
PCT/RU97/00065

(87) International publication number:
WO 97/033653 (18.09.1997 Gazette 1997/40)

(54) METHOD OF EXTINGUISHING A FIRE AND A FIRE-EXTINGUISHING SYSTEM

FEUERLÖSCHVERFAHREN UND FEUERLÖSCHSYSTEM

PROCEDE D'EXTINCTION D'INCENDIES, COMPOSITION D'EXTINCTION DU FEU ET SYSTEME ANTI-INCENDIE

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
SI

(30) Priority: **15.03.1996 RU 96105101**

(43) Date of publication of application:
30.06.1999 Bulletin 1999/26

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RU-C- 2 008 045
RU-C- 2 046 614

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ANNEX E: CV – MR. LUCIANO BORGHETTI

LUCIANO BORGHETTI
Fire Engineering & Life Safety Expert
+ 39-335-246173 HAILB@TIN:IT

Current professional position:

Free Lance Consultant – Specialty Engineering

Experience: 40 Years

Education:
M.S., Strategic Marketing and Business Administration, Universita' Cattolica Sacro Cuore, Milan Italy,
1973 B.S.
Civil Engineering, Istituto Tecnico C. Dell'Acqua, Legnano, Italy, 1967

Associations:
• Member, National Fire Protection Association (NFPA)
• Member, Society of Fire Protection Engineers (SFPE)
• Member, Working Group of the Federal Aviation Authority (FAA/CAA)

Language Skills
• Italian (native)
• English (fluent)
• French (fluent)

Luciano Borghetti with 40 years' experience. He provides fire protection services for European clients, including hazard analysis, special hazard system research and design, and code compliance and equivalency using mathematical and computer models for fire growth and smoke movement. He is also instrumental in assisting with software development and testing, and its associated hardware development
and technical support. Mr. Borghetti executes research projects, conducts fire tests, and manages multiple projects. He develops fire protection programs, code compliance summaries reports, due diligence reports, smoke control criteria and safety/security engineering integration, and facilitates negotiations with various AHJs
.

PROFESSIONAL STANDING
Committees
Chair, International Standards Organization, ISO TC21 SC8 ISO 15779 (Aerosol Extinguishing Technologies).
Convener (Chair) of CEN/TC 191/WG 6 TG 2 on Aerosol Extinguishing Systems.
Italian Expert, CEN/TC 191/WG 6 TG 3 on Gaseous fire-extinguishing systems (Halon Alternatives).
Member, Technical Committee for the Standard on Aerosol Extinguishing Technology, NFPA 2010 (Special Expert).
Member, Working Group of the International Standards Organization, ISO TC21 SC8 ISO 14520 (Halons Alternatives and Carbon Dioxide Standard).
Member, Working Group of the International Maritime Organization (IMO/OMI), for Halons Alternatives and Aerosol Agents.

Member UL CSDS
Member, Working Group of the Italian Ministry of the Environment, Department for the Sea Protection–Service IAR.
Member, Working Group of the Italian Ministry of Transportation.
Technical Expert, Italian Ministry of the Environment to IMO and EU for Halons Decommissioning Program (Mandatory).

PROFESSIONAL HIGHLIGHTS

Director International Business Development, Hughes Associates Inc.- now JENSEN HUGHES, 1999–2015.

Managing Director Hughes Associates Europe srl Milan Italy (former subsidiary of Hughes Associates Inc. now Jensen Hughes), 1999-2014

Description of job responsibilities.
Conducts experimental tests to evaluate the influence of the system hardware in a computer-based software for the prediction of two-phase transient flow of halon alternatives in pipe networks. This effort includes mathematical modeling, generation of data from fully instrumented discharge tests, and analysis of discharge hardware. Performs basic research on the mechanism of extinguishment of aerosol agent (condensed and dispersed).Assisted in the development of a commercial/industrial application software package for the design of clean agent (halon alternatives) extinguishing systems (halocarbon based alternatives and inert gases). Provided significant support to hardware manufacturers to develop suitable system hardware for halon alternatives gaseous agents and technical support during CE-UL-FM listing and approval efforts. Implements special R&D projects for forest fire identification and intervention planning for the Italian Civil Defense. Develops special design for the protection of large volumes for underground and cavern installations. Participates in many fullscale fire tests conducted by JENSEN HUGHES. Acts as Project Manager for full-scale fire testing of halon replacement (for specific agent) for USCG (USA) vessel's machinery spaces–Loss Prevention Council (UK) computer facilities protection and for several contracts to develop Fire Protection Technologies/Systems for major Italian and European fire companies. Project Management/Supervisor for several contracts providing Life Safety Design and Vulnerability/Security investigations for European, Middle East as South America Civil Airports. Develops fire protection programs, code compliance summaries reports due diligence reports, smoke control criteria and safety/security engineering integration, negotiation with the AHJ (Airports Authorities, Fire Marshalls/Fires Brigades, Insurances, and Legal Responsible).

Vice General Manager and Marketing Manager, North America Fire Guardian Technology Inc.
Vancouver BC (N.A.F.G.T. Inc.) and SAFETY HI-TECH S.r.l., Rome, Italy. 1991–1999.
Involved in the development, production, and sales of the NAF fire-extinguishing agents, which are alternatives to halons; specifically, explosion suppression systems for military and commercial aviation, and industrial plants using CFC and halon alternatives, non-halogenated fire retardants for rapid interventions of HAZMAT protection. Market range included Europe, Canada, USA, Africa, Southeast Asia, and joint ventures in Central America, South America, Europe, Middle East, Asia, and Australia.

Sales and Marketing Manager and Assistant of Managing Director, Racal Chubb Fire Security
Ltd Sunbury on Thames, England (and CHUBB-SIA Spa Milano Italy, subsidiaries of Racal Electronics PLC), 1988–1990.

Integrated security systems, including intruder and fire detection systems, special extinguishing systems, software, and building management systems. Individual market range included Europe, Italy, Mediterranean countries, and Chubb branches worldwide.

OMISSIS

ANNEX F: INTERNATIONAL DEFINITIONS

4.0 TERMS AND DEFINITIONS
Authority Having Jurisdiction (AHJ) [NFPA 855 §3.2.2]: An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Battery Energy Storage System (BESS) [UL 9540A §4.2]: Stationary equipment that receives electrical energy and then utilizes batteries to store that energy to supply electrical energy at some future time. The BESS, at a minimum consists of one or more modules, a power conditioning system (PCS), battery management system (BMS), and balance of plant components.

Battery Management System (BMS) [NFPA 855 §3.3.3]: A system that monitors, controls, and optimizes performance of an individual or multiple battery modules.
BESS Event: Failure of the BESS equipment or facilities that results in fire and/or emission of pollutants or smoke.

Cell [UL 9540A §4.3]: The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, separators, container, and terminals. It is a source of electrical energy by direct conversion of chemical energy.

Combustible: Readily or easily ignitable material. Specific definitions vary depending on material: dust, fibers, liquids.

Combustible Liquid [NFC §1.4.1.2]: A liquid having a flash point at or above 37.8°C and below 93.3°C.

Community Risk Analysis (CRA): An evaluation of exposure hazard utilizing a consequence analysis approach for the BESS facility.

Energy Storage Management System (ESMS) [NFPA 855 §3.3.8]: A system that monitors, controls, and optimizes the performance and safety of an Energy Storage System.

Energy Storage Systems (ESS) [NFPA 855 §3.3.9]: One or more devices, assembled together, capable of storing energy to supply electrical energy at a future time.

Energy Storage System Cabinet [NFPA 855 §3.3.9.2]: An enclosure containing components of the Energy Storage System where personnel cannot enter the enclosure other than reaching in to access components for maintenance purposes.

Fire Resistance Rating [NFC §1.4.1.2]: The time, in minutes or hours, that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria, or as determined by extension or interpretation of information derived therefrom as prescribed in the National Building Code of Canada (NBC) 2020.

Fire Risk Assessment (FRA): A process to characterize the risk associated with a BESS fire that addresses the fire scenarios of concern, their probability, and their potential consequences.

Good Utility Practice: means any of the practices, methods and acts engaged in or approved by a significant portion of the electrical utility industry in North America during the relevant time period,

or any of the practices, methods and acts which, in the exercise of reasonable judgment in light of the facts known at the time the decision was made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition. Good Utility Practice is not intended to be limited to optimumpractices, methods or acts to the exclusion of all others, but rather to include all practices, methods or acts generally accepted in North America.

Hazard Mitigation Analysis (HMA) [NFPA 855 §3.3.14]: An evaluation of potential Energy Storage System failure modes and the safety-related consequences attributed to the failures.

Lithium-ion battery: A storage battery with lithium ions serving as the charge carriers of the battery. The electrolyte is a polymer mixture of carbonates with an inorganic salt and can be in a liquid or a gelled polymer form. Lithiated metal oxide is typically a cathode and forms of carbon or graphite typically form the anode.

Module [UL 9540A §4.9]: A subassembly that is a component of a BESS that consists of a group of Cells or electrochemical capacitors connected together either in a series and/or parallel configuration (sometimes referred to as a block) with or without protective devices and monitoring circuitry.

Proponents: A person or company advocating and supporting the connection of BESS equipment/facilities to the Hydro One transmission system.

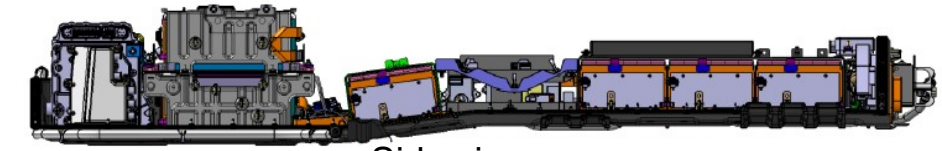
Stationary Energy Storage System [NFPA 855 §3.3.9.7]: An Energy Storage System that is permanently installed as fixed equipment.
Thermal Runaway [UL 9540A §4.11]: The incident when an electrochemical Cell’s temperature increases at an accelerating rate in an uncontrollable fashion sufficient to result in damage to the Cell. The Thermal Runaway progresses when the Cell’s generation of heat is at a higher rate than the heat it can dissipate. This may lead to fire, explosion and gas and smoke evolution.

Transmission Facilities: Refers to facilities owned by an electricity transmitter that form part of or all the transmission system owned by that transmitter, and includes any structures, lines, transformers, breakers, disconnect switches, buses, voltage/current transformers, protection systems, telecommunications systems, cables, and any other auxiliary equipment used for the purpose of conveying electricity.

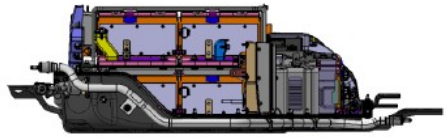
Unit [UL 9540A §4.12]: A frame, rack, or enclosure that consists of a functional BESS facility which includes components and subassemblies such as Cells, modules, battery management systems, ventilation devices and other ancillary equipment.

Module overview

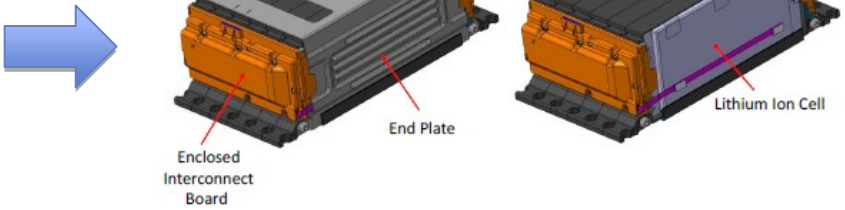
The PHEV Battery pack contains 8 modules with the same dimensions with 12 cells each



Side view



Rear view

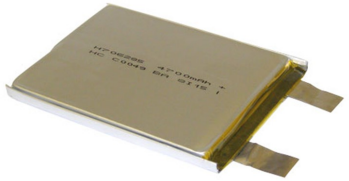


	Unit	LR pack
Dimension (LxWxH)	mm	160 x 300 x 180 (TBC)
Configuration	-	12s1p
Weight (nom.)	Kg	10 kg (TBC)
Nominal Energy (nom.)	kWh	1,47
Voltage (min. / **nom**. / max)	V	32,4 / 44,4 / 49,8
number	-	8

Dual PIM size : 340L x 196W x 210H, 10,8kg ca

To Cell overview

Module and Cell overview



Cell Description	Unit	PHEV Pack
Cell Supplier	-	LG
Cell format	-	pouch
Dimensions	mm	101 (W) x 266 (H) x 12.7 (D)
Weight	gr	554
Cell model	-	Cathode : NMC (622) (*) Anode :graphite
Nominal capacity	Ah	33
V cell max	V	4,15
V cell nom	V	3,7
V cell min	V	2,7
Cell energy (nominal)	Wh	122,1
Energy Density	Wh/L	348
Cell configuration	-	96s1p

* 60% Nichel, 20% Manganese, 20% Cobalt