

Mitigate fire protection challenges related to storage of batteries (with automatic fire sprinkler protection)



Disclaimer

This publication contains potential fire protection solutions or (inspections) methods for certain areas in industrial, commercial or residential facilities and buildings which may be exposed to a fire risk. The selection and design of fire protection solutions, systems and products to mitigate these fire risks are to be executed on a case-by-case basis considering local legislation, regulation and standards and project-specific parameters and lie in the responsibility of the contracted system engineering and installation companies. So far as VdS Nederland provide technical information or (seen to be) act(ing) as a consultant, notice that this information or consulting does not belong to the scope of VdS Nederland accredited services, this is done for generally purpose, not for a project specific issue, free of charge and without any liability.

Personal introduction: Marcel Ruesink



- Managing director of VdS Nederland
 - VdS Nederland Accredited inspection body
 - Inspecting: NFPA, EN, (VdS) CEA 4001, FM, ISO, etc.
- Memberships:
 - Chairman of RUUV (CE marking via EOTA)
 - Chairman of VBE (Verenigde Brandveiligheid Experts)
 - Board member of VIVB (Vereniging van Inspectie-Instellingen voor Veiligheid en Brandveiligheid)
 - Member CFPA (Confederation of Fire Protection Associations Europe)
 - Technical expert at CEN TC191 W5, W6 & W10 (EN12845 & EN14972)

Agenda

Title:

Mitigate fire protection challenges related to storage of batteries (with automatic fire sprinkler protection)

Agenda:

Section 1: Electrification challenges

- Evolution
- Congestion: the new buzzword
- Electrification

Section 2: Fire challenge of batteries

- Footage thermal runaway
- Abuse is the genesis
- The four stages
- Battery risk in storage or production

Section 3: FM global datasheets (excl DS 5-33)

- Fire protection criteria of non-storage area's
- Fire protection criteria of storage area's
- Footage fire test

Section 4: VdS CEA 4001 TB3

- Scope and limitations
- General guidelines
- Definition (storage) rack type
- Sprinkler design of storage exceeding 2 m³
- Sprinkler design of storage exceeding 2 m³ ST4 @ 15 m
- Available at www.vds-nederland.nl

Section NFPA 855 (Stationary Energy Storage Systems)

- NFPA 855 Scope
- NFPA 855, Sprinkler protection
- Clean agent system feature selection

Section 6: Dutch CCV inspection protocol

- Dutch system of quality assurance
- VdS Nederland accreditation under 17020



01

Electrification challenges

Evolution of engery

Wood

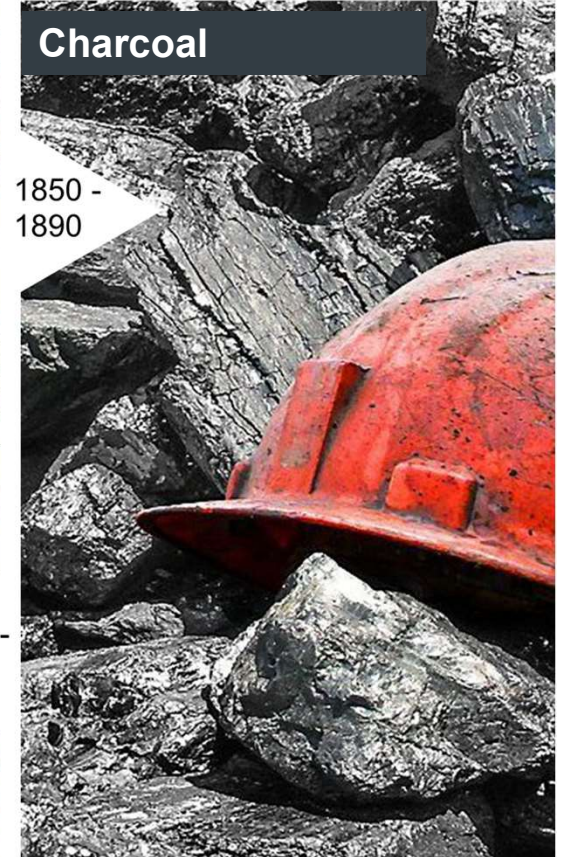


Peat



1400 -
1600

Charcoal



1850 -
1890

Sustainable energy



Heden

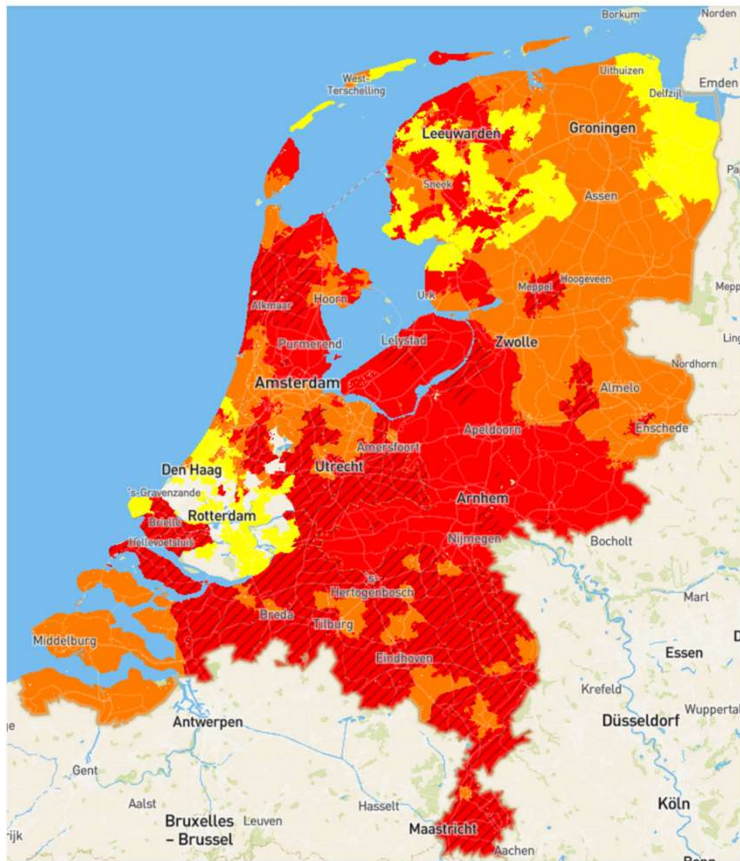
Natural gas



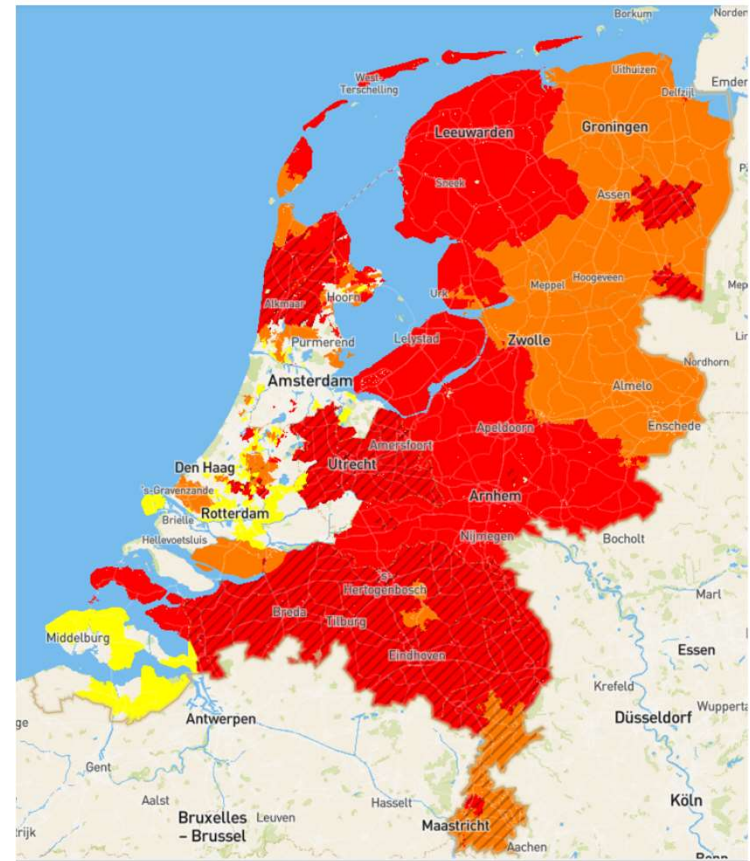
1960 -
1970

Congestion: the new buzzword

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Bijgewerkt: 04-04-2024 09:21



Capaciteitskaart invoeding elektriciteitsnet
Bijgewerkt: 04-04-2024 09:21



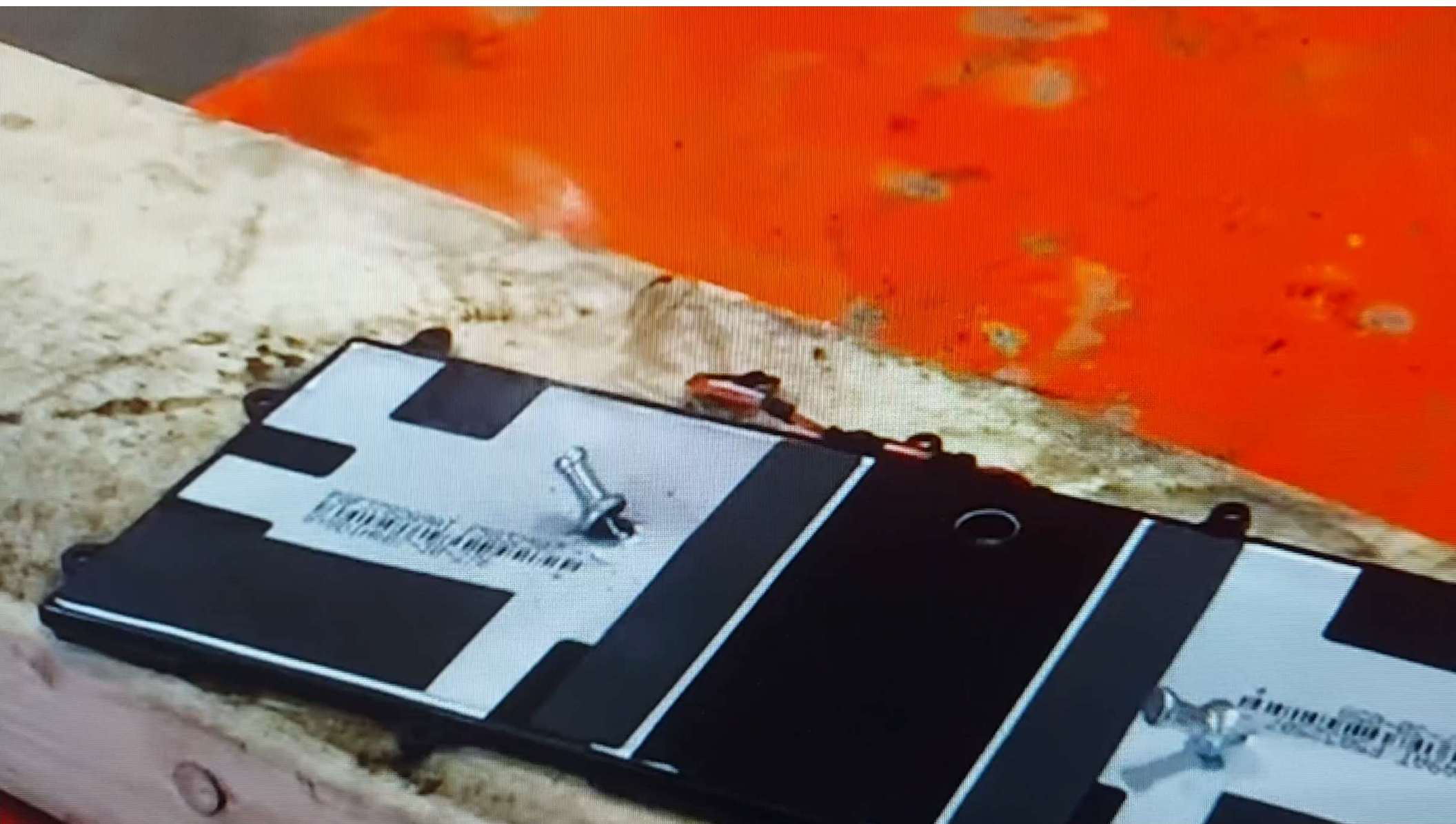
Electrification



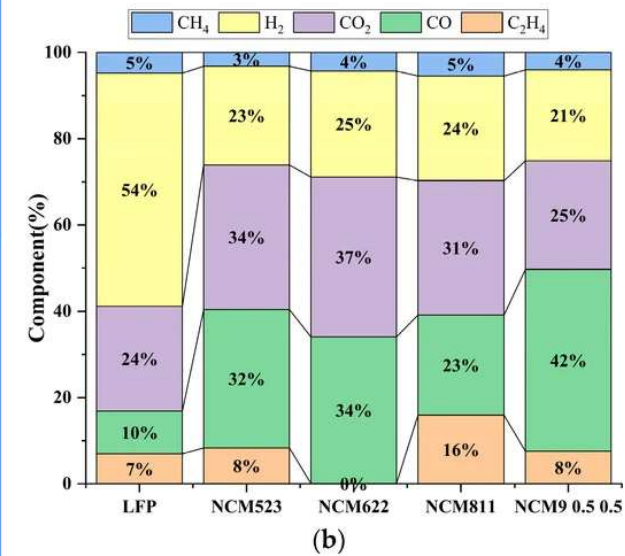
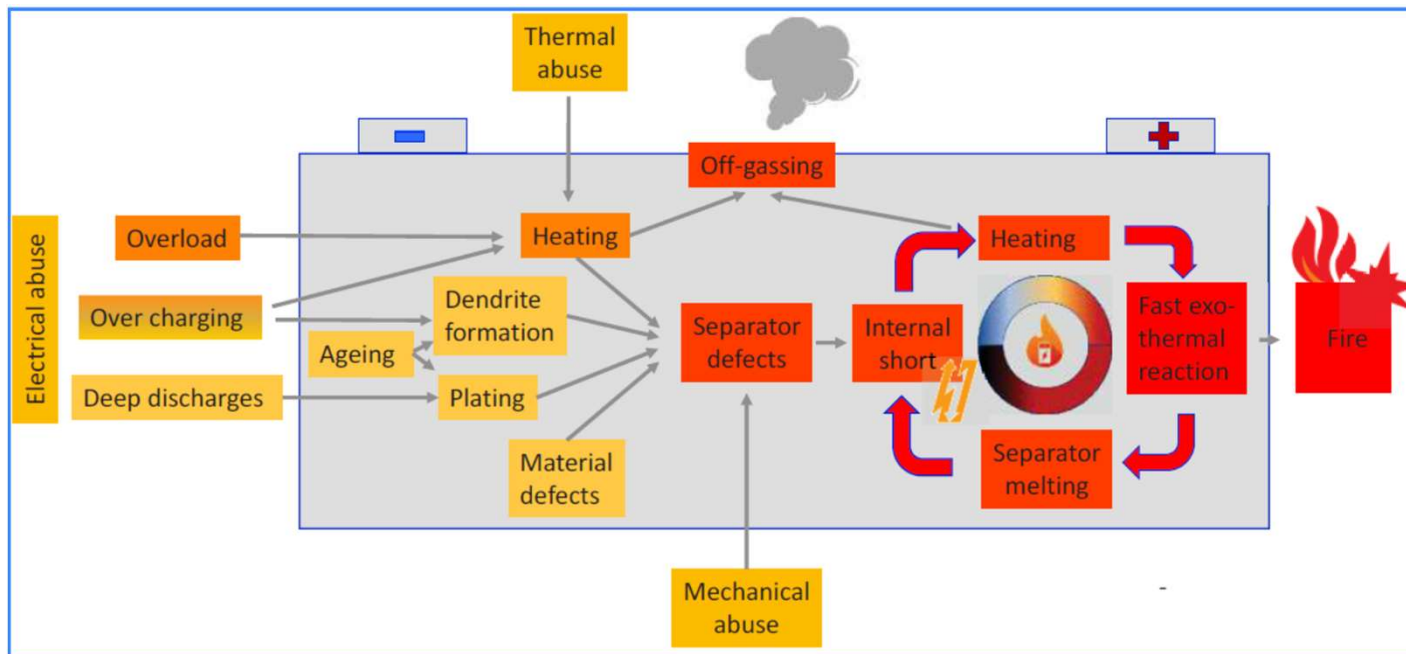


02

Fire challenge of batteries



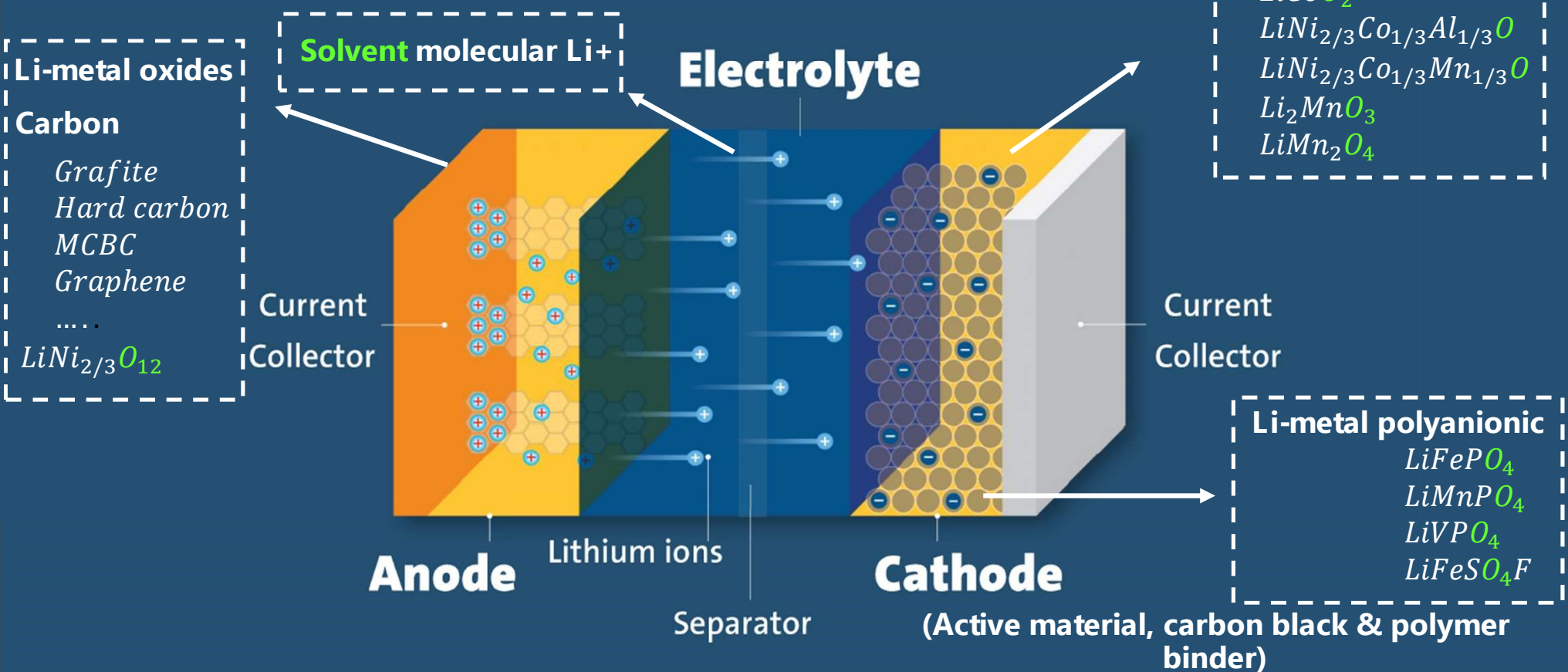
Abuse is the genesis



<https://www.mdpi.com/2079-9292/12/7/1603>

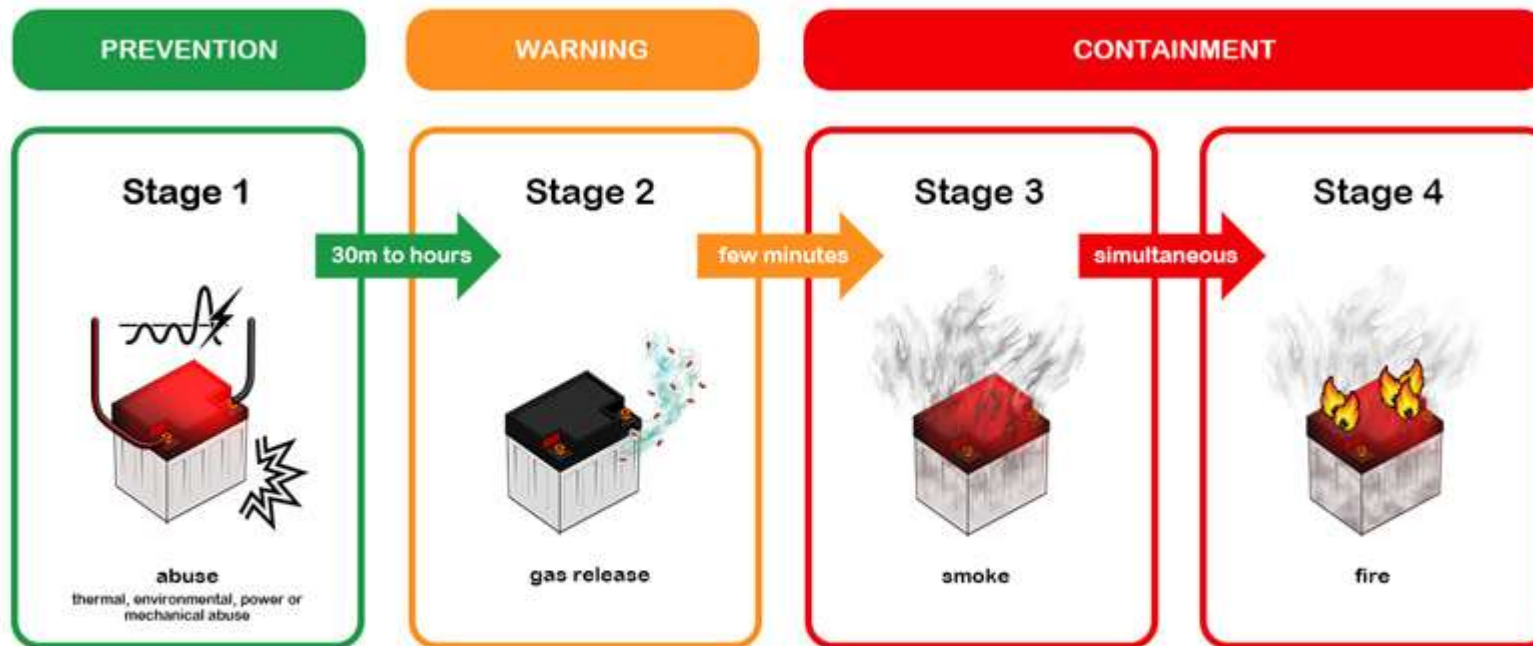
LFP battery technology is a type of lithium-ion battery using lithium iron phosphate (LiFePO₄) as the cathode material

Fire behaviour: the components

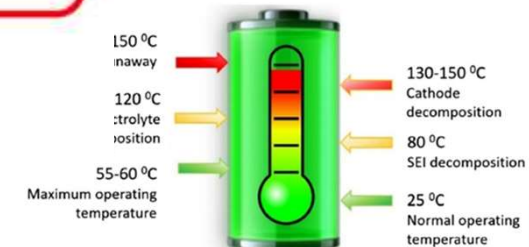


Source: Gao, Jian, Si-Qi Shi, and Hong Li. "Brief overview of electrochemical potential in lithium-ion batteries." *Chinese Physics B* 25.1 (2015): 018210.

The four stages



Infrasensing.com



Battery risk in storage or production





03 FM Global data sheets

Excluding FM DS 5-33

FIRE PROTECTION FOR NONSTORAGE OCCUPANCIES

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Ceiling height	till 9,0 m [mm/min @ m²]	till 13,5 m [mm/min @ m²]	till 18 m [mm/min @ m²]	till 30 m [mm/min @ m²]
Design at HC-3	12 @ 230	12 @ 340	20 @ 280	24 @ 110

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Fire protection Non-storage

FM DS 3-26 (October 2001) @ 2.3.2.5

- Limit storage area to no more than 20 m²
- Separate multiple storage areas by aisles not less than 3 m
- Maximum storage height at 1,8 m
- State Of Charge (SOC) 60% at max

Fire protection of storage

FM DS 8-1

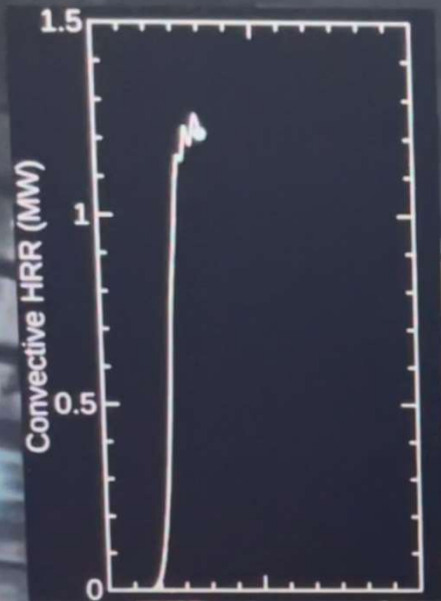
- Any finished products if:
- Maximum ceiling height 12 m
 - SOC max. 60%
 - New batteries up to 60% SOC (Table 2.4.2.1)
 - Used/refurbished batteries and SOC > 60% with in rack protection

<i>Li-ion Cell/Module State of Charge</i>	<i>Ceiling Height</i>	<i>Storage Height</i>	<i>Storage Arrangement</i>	<i>Packaging</i>	<i>Ceiling Protection (QR sprinklers only)</i>	<i>In-Rack Protection</i>
≤ 60%	≤ 40 ft (12 m)	Maximum 3 levels of storage up to a total height of 15 ft (4.5 m)	Open-frame rack, solid-pile or palletized	Wood crate, metal encased or corrugated carton with cellulosic and/or unexpanded plastic internal packaging only	K22.4 or K25.2 (K320 or K360) 12 @ 35 psi (2.4 bar)	NA
				Corrugated carton with expanded plastic internal packaging	CEP per 8-9*	NA
				Plastic external packaging	UUP per 8-9*	NA
	> 40 ft (12 m)	NA	Open-frame rack	Uncartoned	Per surrounding occupancy.	See Section 2.4.2.2
> 60%	NA			Cartoned or uncartoned	Per surrounding occupancy.	See Section 2.4.2.2

Tab. 2.4.2.1
Protection of Lithium-Ion Cells and Modules

2.4.2.4 Develop a pre-incident plan [...]. The plan should include manual fire protection methods to be employed and a designated location outside of the facility to which damaged and impacted cells can be moved.

2.4.2.5 Develop a post-incident recovery plan that addresses the potential for reignition of li-ion batteries, as well as the removal and disposal of any damaged or impacted cells, modules or products.



01:19



A blue-tinted photograph of two men in a warehouse. The man on the left is pointing his right index finger towards the upper left. Both men are wearing dark jackets over light-colored shirts. The man on the right has a name tag that reads "W. SCHNEIDER". The background shows industrial shelving filled with boxes.





04 | VdS CEA 4001 TB3



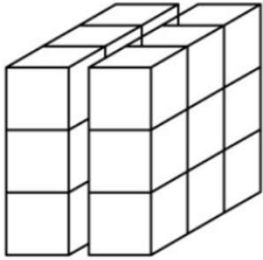
Scope and limitations

- Testing and research is ongoing. The following design criteria for sprinkler protection reflects the current (2022) state of research and design
- Design is based on tests on Li-Ion batteries
- Pending further testing and research, the guidelines below can also be used for Li-Polymer and Li-Fe-Phosphate
- <https://vds-nederland.nl/normen-richtlijnen/technisch-informatieblad-voor-opslag-van-lithium-ion-batterijen/>
- [Research test by FMglobal](#)

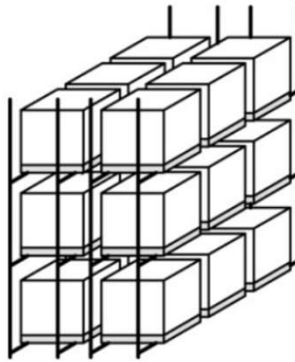
General guidelines

Configuration	Example / typical situation	Requirement
Small batteries (<100Wh)	Laptop in offices, electric tools in a workshop, Display of electrical equipment in retail....  	No additional requirements: The sprinkler design provides sufficient protection for this risk.
Storage of goods containing Li-ion batteries (limited to 1kWh per item)	Consumer goods such as electro-technical, computers, drilling machines  	The classification of goods containing Li-ion batteries is HHS3 or the corresponding classification by plastic content, whichever predominates.
Storage of used or damaged Li-ion batteries	More than 0.5 m ³	<ul style="list-style-type: none"> • Dedicated container (no other goods in the container) • Specially designed container for batteries • Stored separately in boxes with a high level of fire rating • Limited to 1 level on ground (no piled storage) • Ceiling protection with design no less than 12.5 mm/min over 260 m² • Note: If less than 0,5 m³ per design area no specific requirement shall be taken into account.
Limited storage of Li-Ion batteries, e.g. in production areas	No more than 2 m ³ (Including packaging) within an area of operation. Batteries must be contained in cardboard boxes and 60% SOC. This could be in one single block or separated in several smaller units.	<ul style="list-style-type: none"> • Protect as per HHS3. Where ceiling protection only is provided, the design shall be no less than 12.5 mm/min over 260 m² or ESFR or CMSA protection. • Where in-rack protection is provided, the design shall be as per HHS3 with no additional requirement.

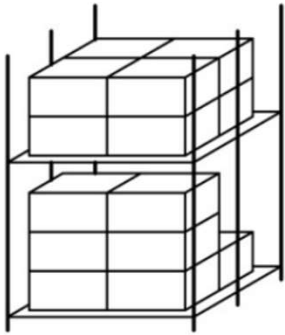
Definition (storage) rack type



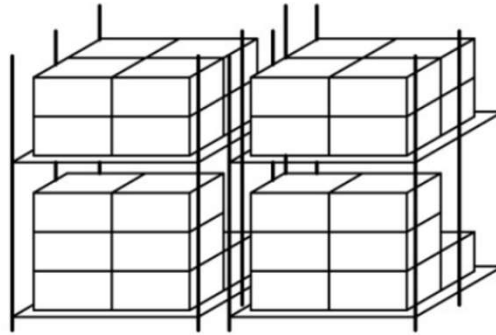
Freistehende Lager (ST 1)



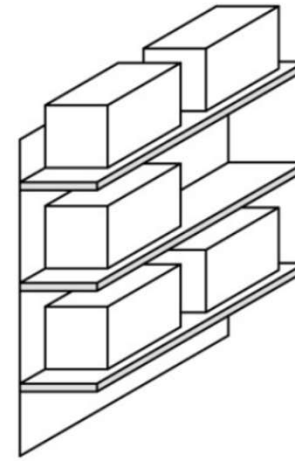
Paletten-Regallager (ST 4)



Einreihige Ständerlager (ST 2)



Mehrreihige Ständerlager (ST 3)



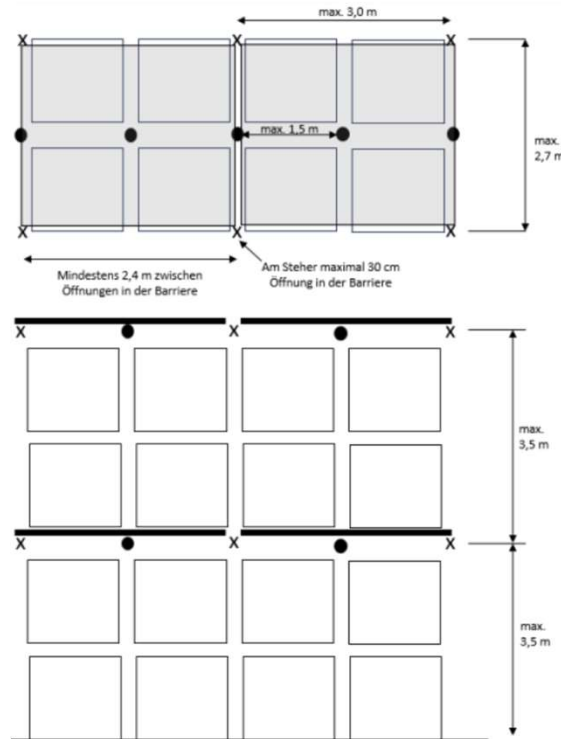
Geschlossene oder
gelattete Zwischenböden (ST 5/6)

Sprinkler design of storage exceeding 2 m³

Storage configuration	Max ceiling height (m)	Max storage height (m)	Sprinkler design			Comments
			Type of sprinkler	Density (mm/min)	Area of operation (m ²)	
ST1	9	1 level on floor not exceeding 1,5m height	Spray sprinkler minimum K115, 68°C	12,5	260 (wet) 325 (dry)	
ST1	12,2	1 level on floor not exceeding 1,5m	Spray sprinkler minimum K160, 68°C	17,5	260 (wet)	Wet system only
ST1/ST2/ST3/ST4	12,2	4,6 (measured from floor to top of storage)	ESFR K 360 68°C or 74°C		12 spk @2,4 bar	Ceiling protection only. If mixed commodities, the maximum storage height remains 4,6m. Further more: * SOC of 60% * 50 kWh max / battery * Limited area per 5.02 VdS CEA 4001
ST4	15	Ceiling height minus 1m (clearance)	Ceiling :Spray sprinkler minimum K115, 68°C In-rack : Spray sprinkler minimum K115, quick response , 68°C	12,5	260 (wet) (Ceiling sprinkler water demand and the IRAS demand shall be balanced at the point of connection)	Wet system only In-rack protection according to figure F 3a for cartoned batteries. In-rack protection according to figure F 3b for uncartoned batteries.

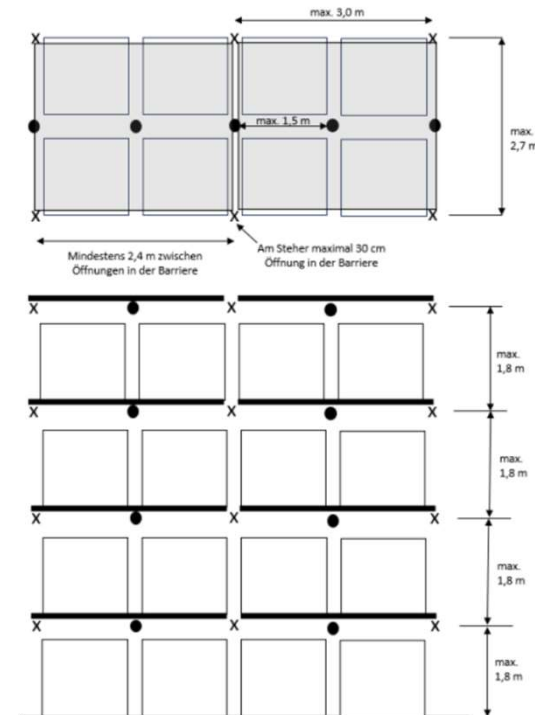
Sprinkler design of storage exceeding 2 m³ ST4 @ 15 m ceiling height

Vertical: 3.5 m
Horizontally 1.5 m/3.0m
0.7 mm/10 mm
horizontal barrier
K115/K160 @ 216 l/min
4 spk @ 2 lines
Protection above the top
storage level
Restriction to lower
levels possible



In-rack protection for
cartoned batteries

Vertical: 1.8 m
Horizontally 1.5 m/3.0 m
0.7 mm/10 mm horizontal
barrier
K115/K160 @ 216 l/min
4 spk @ 2 lines
Protection above the top
storage level
Restriction to lower levels
possible



In-rack protection for
uncartoned batteries



05

NFPA 855

Standard for the Installation of Stationary Energy Storage Systems

NFPA 855 Scope (see also FM DS 5-33)

Scope NFPA 855:

Free accessible on the internet

Click [here](https://submittalsarchive.nfpa.org/TerraViewWeb/ViewerPage.jsp?id=855-2020.ditamap&pubStatus=FDR)

Applies to stationary ESS situation and storage of lithium metal or lithium-ion batteries:

- Design
- Construction
- Installation
- Commissioning
- Operating
- Decommissioning

https://submittalsarchive.nfpa.org/TerraViewWeb/ViewerPage.jsp?id=855-2020.ditamap&pubStatus=FDR

NFPA 855... x

Public Reports

NFPA 855

NFPA Document Information Pages

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FDR 855 Home

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- Chapter 2 Referenced Publications
- Chapter 3 Definitions
- Chapter 4 General
- Chapter 5 System Interconnections
- Chapter 6 Commissioning
- Chapter 7 Operation and Maintenance
- Chapter 8 Decommissioning
- Chapter 9 Electrochemical Energy Storage Systems
- Chapter 10 Capacitor Energy Storage Systems

1.1* **Scope. (Reserved)**

This standard applies to the design, construction, installation, commissioning, operation, maintenance, and decommissioning of stationary energy storage systems (ESS), including mobile and portable ESS installed in a stationary situation and the storage of lithium metal or lithium-ion batteries.

Pls [12] FR-18 Hide Legislative

1.2 **Purpose.**

This standard provides the minimum requirements for mitigating the hazards associated with ESS and lithium metal or lithium-ion battery storage.

Pls [17] FR-19 Hide Legislative

1.3* **Application.**

This standard applies shall apply to ESS installations exceeding the values shown in Table 1.3 and lithium metal or lithium-ion storage.

Table 1.3 Threshold Quantities per Each Fire Area

ESS Technology	Aggregate Capacity ^a	
	kWh	MJ
Battery ESS		
Lead-acid, all types	70	252
Nickel including: Ni-Cad, Ni-MH, and Ni-Zn ^b	70	252
Lithium-ion, all types	20	72
Sodium nickel chloride	20 (70 ^b)	72 (252 ^b)
Flow batteries ^c	20	72
Other battery technologies	10	36
Batteries in one- and two-family dwellings and townhouse units	1	3.6
Capacitor ESS		
Electrochemical double layer capacitors ^d	3	10.8
Other ESS		
All other ESS	70	252
Flywheel ESS (FEES)	0.5	1.8

Hello ruesinkmarcel@gmail.com NFPA Document Information Pages

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NFPA 855, Sprinkler protection

The screenshot shows a web browser displaying the NFPA 855-2020 document. The browser's address bar shows the URL: <https://submittalsarchive.nfpa.org/TerraViewWeb/ViewerPage.jsp?id=855-2020.ditama&pubStatus=FDR>. The browser's tabs show "NFPA 855-2020" and "Public Reports". The document's table of contents is visible on the left, with blue arrows pointing to "Chapter 14 Storage of Used or Off-Specification Batteries" and "Annex G Guide for Suppression and Safety of Lithium-Ion Battery (LIB) Energy Storage Systems (ESS)". The main text area shows the following sections:

- G.6 Fire Protections Systems and Mitigation Strategies, Including System Goal, Water Duration, and Water Application Strategies.**
- G.6.1 Suppression Technologies.**
- G.6.1.1 Sprinklers.**

There are two known publicly available large-scale fire tests, equivalent to UL 9540A, supporting the use of ceiling-level sprinkler systems for the protection of LIB ESS. One test evaluated a 83 kWh system made up of lithium-iron-phosphate batteries and another evaluated a 125 kWh system made up of nickel-manganese-cobalt-oxide batteries. In both tests, protection was provided by ceiling sprinklers having a K-factor of 5.6 gpm/psi^{1/2}, operating at a discharge pressure of 2 bar (29 psi) to provide a nominal discharge density of 0.3 gpm/ft². The results show that large-scale testing is needed to determine the following:

- (1) Ceiling sprinkler protection can prevent or delay a fire from spreading beyond the ESS rack of origin, but obstructions caused by the design of ESS system (e.g., solid-metal cabinet encompassing tightly packed battery modules) limit the ability to suppress or extinguish fire within the rack of origin.
- (2) Minimum space separation has been provided from the ESS to surrounding combustibles to limit the potential for additional fire spread, including nearby ESS racks
- (3) Minimum space separation has been provided from the ESS to surrounding noncombustible objects to limit the potential for damage
- (4) If fire does spread to an adjacent ESS rack (i.e., installed side-by-side), it does not impact the design and electrical capacity of battery components as well as the design of the ESS cabinet that houses the battery components (e.g., battery modules)
- (5) Adequate cooling of the batteries is provided to prevent reignition, which can occur after a fire appears to be extinguished. A fire watch should be present until all potentially damaged ESS equipment containing Li-ion batteries is removed from the area following a fire event.
- (6) Adequate building component rating is provided to withstand the expected intensity and duration of an ESS fire event.

The wide range of results highlight the need for large-scale fire testing to evaluate sprinkler protection for each unique ESS to ensure the expected level of protection is provided. Protection system considerations that would require a large-scale fire test include a reduction in the specified sprinkler system design density, a reduction in the minimum separation distance from nearby combustible and noncombustibles, changes in ESS cabinet, or increasing ESS electrical capacity.

- G.6.1.2 Spray Systems. (Reserved)**
- G.6.1.3 Water Mist Systems.**

Water mist is a water spray for which the 99 percent of the total volume of liquid (Dv0.99) is distributed in droplets with a diameter smaller than 1000 microns at the minimum design operating pressure of the water mist nozzle.

- G.6.1.3.1 Different Types of Water Mist Systems.**

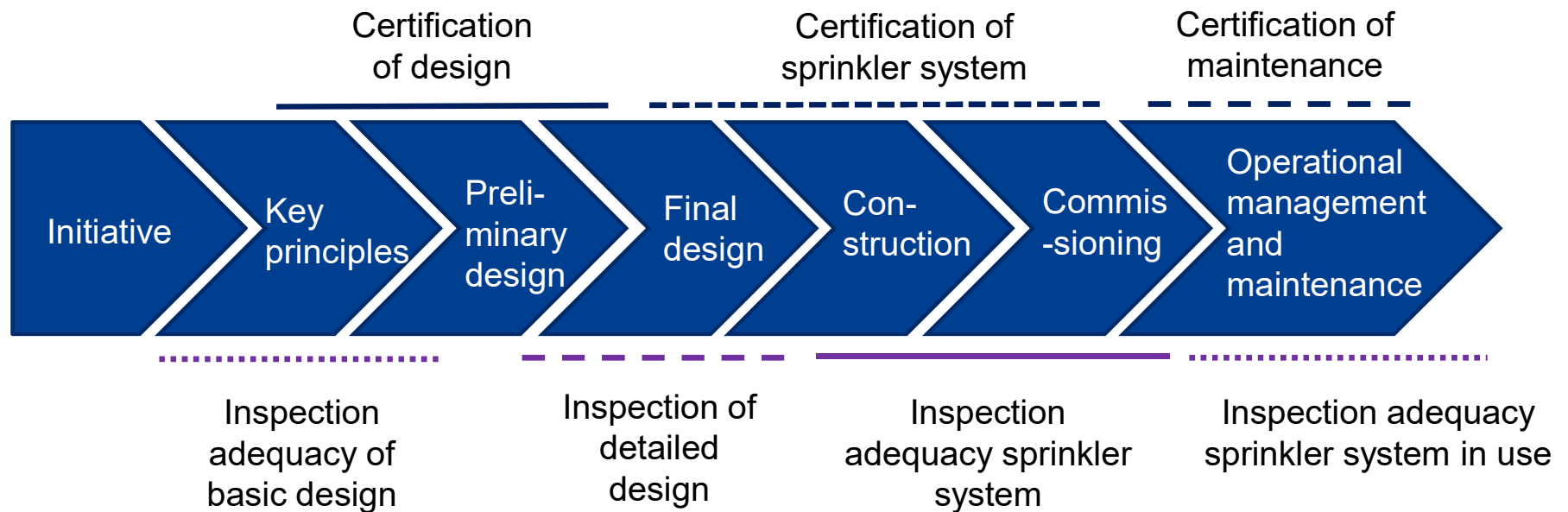
The types of water mist systems are as follows:

At the bottom of the page, the footer shows "Hello ruesinkmarcel@gmail.com" and "NFPA Document Information Pages".

A blue-tinted photograph of two men in a warehouse. The man on the left is pointing his right index finger towards the left. Both men are looking in that direction. The man on the right is wearing a jacket with a name tag that reads 'W. SCHNEIDER'. The background shows industrial shelving.

04 | Dutch CCV inspection protocol

Dutch system of quality assurance



- Independent third party certification and inspection bodies
- Inspection and certification accredited by Dutch accreditation body RvA

Accreditaties

Er zijn geen partijen betrokken bij het eigendom of het bestuur van VdS Nederland B.V. die mogelijk een belang hebben bij de items/objecten die door VdS Nederland B.V. worden geïnspecteerd.

VdS Nederland B.V. voert inspecties uit voor derden en is niet betrokken bij het ontwerp, de productie, de levering, de installatie, het gebruik of het onderhoud van de te onderzoeken items/objecten. Iedere vorm van druk (commercieel, financieel of anderszins) die de inspecties kan beïnvloeden, moet worden voorkomen en waar dit wél optreedt, dient dit direct gesignaleerd te worden opdat maatregelen kunnen worden getroffen.



Certificaat accreditatie EN ISO/IEC 17020



Bijlage bij accreditatieverklaring: scope van accreditatie (PDF, 1,3 Mb).

Daarnaast mag VdS Nederland B.V. met trots het EBN certificaat Veiligheidsmanagementsysteem voeren:

Thanks for your attention