Vikings Lithium-Ion Protection Line-Up

The fire hazard presented by Lithium-ion batteries depends on where in the production process the batteries are located. FMDS 7-112 *Lithium-ion Battery Manufacturing & Storage* differentiates the fire hazard for manufacturing areas, formation and aging areas, battery storage areas and finished product storage areas. Viking sprinklers protect them all.

Manufacturing Areas

Manufacturing areas would be protected in accordance with the appropriate FM Data Sheet based on the hazards present. FMDS 3-26 *Fire Protection for Nonstorage Occupancies* would classify these spaces as an HC-3. Design densities for HC-3 vary based on ceiling height. Table 1 shows the guidelines for HC-3 based on ceiling height. Densities in these areas range from 0.3 to 0.6 gpm/ft^2. Sprinkler selection for these areas consists of any Viking commercial sprinkler capable of delivering the density at a reasonable pressure.

Table 1

Guidelines for HC-3 Based on Ceiling Height

Hazard Category	Ceiling Height up to 30ft		Ceiling Height 30-45ft		Ceiling Height 45-60ft		Ceiling Height 60-100ft	
	gpm/ft^2							
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
HC-3	0.3/2500	0.3/3500	0.3/3600	0.3/4600	0.5/3000	0.5/4000	0.6/1200	Unavailable

Formation and Aging Areas

Formation and aging areas are short-term storage spaces where the cells go through a cycle of charging and discharging. Because this is the initial testing, there is a higher probability that batteries in this area experience failure resulting in thermal runaway. This results in a need for specific sprinkler system design guidance provided in FMDS 7-112 and FMDS 8-9.

Protection for these areas is based on the hazard classification of the surrounding occupancy and the configuration of the storage; open frame or bin-box/enclosed chamber. Again, the ceiling sprinkler selection for these areas consists of any Viking commercial sprinkler capable of delivering the density at a reasonable pressure and, if the batteries are positioned in racks similar to open-rack storage, then FM Approved in-rack sprinklers would be required. Unlike previous guidance, FMDS 7-112 does not establish a minimum K-factor for in-rack sprinklers. Viking has numerous K5.6 and K8.0 sprinklers that are FM Approved for in-rack use. FMDS 7-112 sets a

minimum operating pressure of 7 psi for these sprinklers and a minimum pressure of 10 psi for K11.2 sprinklers.

Table 2

FM Approved Viking Storage Sprinkler Line-up – In-Rack Sprinklers

K5.6	VK102, VK110, VK302, VK303, VK550, VK552, VK556
K8.0	VK202, VK206, VK352, VK560, VK562, VK566
K11.2	VK377, VK536

Incidental Storage

This type of storage is defined as that which is normal for the occupancy. Incidental storage is dynamic, it is used in the manufacturing process and replaced as the storage runs out. Depending on the product and process, the batteries will be stored in a number of types of packaging and configurations and have a variety of States of Charge. If the batteries are stored in metal or cardboard boxes there is no specific sprinkler design guidance for this storage other than that of the occupancy provided that the State of Charge of the batteries is maintained under 60%.

However, if the batteries are stored in unexpanded plastic containers then the commodity is classified as Unprotected, Uncartoned Plastic (UUP) and sprinklers are selected based on ceiling height, K-factor and response characteristics.

Table 3

FM Approved Viking Incidental Storage Sprinkler Line-up

		Quick-Response					Standard-Response		
Commodity	**Max Ceiling Height**	**K11.2**	**K14.0**	**K16.8**	**K22.4**	**K 25.2**	**K11.2**	**K19.6**	**K25.2**
Wet System, Pendent Sprinklers, 160F, Number of AS @ psi									
		VK377 VK536	VK500	VK503	VK506	VK510	VK536	VK592	
UUP	30	25 @ 50 1979 gpm	10 @ 62 1102 gpm	10 @ 43 1102 gpm	14 @ 24 1536 gpm	14 @ 19 1537 gpm	25 @ 50 1979 gpm	25 @ 16 1960 gpm	
	45		10 @ 62 1102 gpm	10 @ 43 1102 gpm	14 @ 24 1536 gpm	14 @ 19 1537 gpm			
	60				10 @ 50 1580 gpm	10 @ 40 1593 gpm			
Wet System, Upright Sprinklers, 160F, Number of AS @ psi									
		VK531	VK520				VK530 VK540		VK598
UUP	30	25 @ 50 1979gpm	10 @ 62 1102 gpm				25 @ 50 1979 gpm		25 @ 10 1990 gpm
	45		10 @ 62 1102 gpm						

Note: This table is extracted and modified from FMDS 7-112, Table 2.4.3.2

Finished Product Storage Area

This type of storage is described as consumer products that employ a finished battery within the product. Electronic devices such as laptop computers, tablets, cell phones as well as household products like lawn equipment, vacuums or toys.

Viking storage sprinklers provide protection based on the commodity classification of the finished product, storage arrangement, ceiling height, sprinkler response and sprinkler orientation as found in FMDS 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.

Table 4

FM Approved Viking Storage Sprinkler Line-up – Ceiling Sprinklers

K11.2	VK377, VK530, VK531, VK540, VK536
K14.0	VK500, VK520
K16.8	VK503, VK580
K19.6	VK592
K22.4	VK506
K25.2	VK510, VK595(EC), VK598
K28.0	VK514

New or Refurbished Battery Storage

This category consists of battery cells and modules in storage and includes products such as finished electric vehicle modules or packs. This storage can be in either piled or in-rack configuration and FMDS 7-112 provides the commodity classification based on the packaging and then refers to FMDS 8-9 for the protection options.

This section revises the guidance found previously in FMDS 8-1 by separating the storage configurations into two separate tables. In FMDS 7-112, Table 2.4.5.1-1 provides guidance on commodity classification for Solid-Piled or Palletized storage arrangements and Table 2.4.5.1-2 provides guidance for Open-Frame Rack Storage.

For Piled and Palletized storage Table 2.4.5.1-1 details four protection scenarios, all of them limited to 60% state of charge, 40 ft. ceiling height and 15 ft. storage height.

Table 5

FMDS 7-112, Table 2.4.5.1-1

Maximum Lithium-ion Cell/Module State of Charge	*Maximum Ceiling Height*	*Storage Height*	*Packaging*	*Protection (QR Sprinklers only)*
60%	40 ft (12 m)	15 ft (4.5 m)	Wood crate, metal encased or corrugated carton with cellulosic and/or unexpanded plastic internal packaging only	CUP per Data Sheet 8-9 (Note 1)
			Corrugated carton with expanded plastic internal packaging	CEP per Data Sheet 8-9 (Note 1)
			Unexpanded Plastic external packaging	UUP per Data Sheet 8-9 (Note 1)
			Unexpanded Plastic external packaging with > 40% expanded plastic (by volume) inside	UEP per Data Sheet 8-9 (Note 1)

Scenario 1

The following table shows the various Viking quick response sprinklers and the base system demands for the protection of Cartoned Unexpanded Plastics in a Piled Storage Arrangement at ceiling heights 30 ft. and above.

Table 6

CUP Piled Storage

CUP Piled Storage								
			Pendent			Upright		
Max. Ceiling Height	**K-Factor**	**SIN**	**Design**	**Flow**		**SIN**	**Design**	**Flow**
30 ft.	11.2	VK377	25 @ 50	1980		VK531	25 @ 50	1980
	14.0	VK500	12 @ 50	1188		VK520	12 @ 50	1188
	16.8	VK503	12 @ 35	1192				
	22.4	VK506	9 @ 20	902				
	25.2	VK510	9 @ 20	1014				
35 ft.	14.0	VK500	9 @ 75	1091				
	16.8	VK503	9 @ 52	1090				
	22.4	VK506	9 @ 28	1066				
	25.2	VK510	9 @ 22	1063				
40 ft.	14.0	VK500	9 @ 75	1091				
	16.8	VK503	9 @ 52	1090				
	22.4	VK506	9 @28	1066				
	25.2	VK510	9 @ 22	1071				

Scenario 2

The following table shows the various Viking quick response sprinklers and the base system demands for the protection of Cartoned Expanded Plastics in a Piled Storage Arrangement at ceiling heights 30 ft. and above.

Table 7

CEP Piled Storage

CEP Piled Storage								
			Pendent			Upright		
Max. Ceiling Height	K-Factor	SIN	Design	Flow		SIN	Design	Flow
30 ft.	11.2	VK377	25 @ 50	1979		VK531	25 @ 50	1979
	14.0	VK500	12 @ 50	1187		VK520	12 @ 50	1187
	16.8	VK503	12 @ 35	1192				
	22.4	VK506	12 @ 25	1344				
	25.2	VK510	12 @ 20	1352				
35 ft.	22.4	VK506	12 @ 63	2133				
	25.2	VK510	12 @ 50	2138				
40 ft.	22.4	VK506	12 @ 75	2327				
	25.2	VK510	12 @ 60	2342				

Scenario 3

The following table shows the various Viking quick response sprinklers and the base system demands for protection of Uncartoned Unexpanded Plastics in a Piled Storage Arrangement at ceiling heights 30 ft. and above.

Table 8

UUP Piled Storage

UUP Piled Storage								
			Pendent			Upright		
Max. Ceiling Height	**K-Factor**	**SIN**	**Design**	**Flow**		**SIN**	**Design**	**Flow**
30 ft.	11.2	VK377	25 @ 50	1979		VK531	25 @ 50	1979
	14.0	VK500	9 @ 100	1260		VK520	12 @ 32	950
	16.8	VK503	9 @ 70	1265				
	22.4	VK506	9 @ 50	1425				
	25.2	VK510	9 @ 40	1434				
35 ft.	22.4	VK506	12 @ 63	2133				
	25.2	VK510	12 @ 50	2138				
40 ft.	22.4	VK506	12 @ 75	2327				
	25.2	VK510	12 @ 60	2342				

Scenario 4

The following table shows the various Viking quick response sprinklers and the base system demands for protection of Uncartoned Expanded Plastics in a Piled Storage Arrangement at ceiling heights 30 ft. and above.

Table 9

UEP Piled Storage

UEP Piled Storage							
			Pendent		Upright		
Max. Ceiling Height	K-Factor	SIN	Design	Flow	SIN	Design	Flow
30 ft	14.0	VK500	9 @ 100	1260	NO FM APPROVALS FOR UPRIGHT SPRINKLERS AT THESE CEILING HEIGHTS		
	16.8	VK503	9 @ 70	1265			
	22.4	VK506	9 @ 50	1425			
	25.2	VK510	9 @ 40	1434			
40ft	25.2	VK510	20 @ 75	4364			

For protection of storage in open racks Table 2.4.5.1-2 is a revision of Table 2.4.2.1 of the previous edition of FMDS 8-1. There are now seven packaging scenarios instead of five and there are expanded references to FMDS 8-9. The revisions to this table are highlighted in yellow below.

Table 10

Table 2.4.5.1-2 - Revision of Table 2.4.2.1

Lithium-ion Cell/Module State of Charge	*Maximum Ceiling Height*	*Maximum Storage Height*	*Packaging*	*Ceiling Protection (QR sprinklers only)*	*In-Rack Protection*
≤ 60%	40 ft (12 m)	15 ft (4.5 m) (Maximum of 3 tiers)	Wood crate, metal encased or corrugated carton with cellulosic and/or unexpanded plastic internal packaging only	CUP per Data Sheet 8-9 (Note 1)	NA
			Corrugated carton with expanded plastic internal packaging	CEP per Data Sheet 8-9 (Note 1)	NA
			Unexpanded plastic external packaging with ≤ 40% expanded plastic (by volume) inside	UUP per Data Sheet 8-9 (Note 1)	NA
			Unexpanded plastic external packaging with > 40% expanded plastic (by volume) inside; or expanded plastic external packaging	UEP per Data Sheet 8-9 (Note 1)	NA
			Uncartoned	Per surrounding occupancy	See Section 2.4.2.2, 2.4.5.5, and 2.4.5.6.
	> 40 ft (12 m)	NA	Cartoned or uncartoned	Per surrounding occupancy	Per Section 2.4.5.4
> 60%	NA		Cartoned or uncartoned	Per surrounding occupancy	Per Section 2.4.5.4

Scenario 1

The following table shows the various Viking quick response sprinklers and the base system demands for the protection of Cartoned Unexpanded Plastics in an Open-Rack Storage Arrangement at ceiling heights 30 ft. and above.

Table 11

CUP Open-Rack Storage

CUP Open-Rack Storage								
			Pendent			Upright		
Max. Ceiling Height	K-Factor	SIN	Design	Flow		SIN	Design	Flow
30 ft.	14.0	VK500	12 @ 50	1187				
	16.8	VK503	12 @ 35	1192				
	22.4	VK506	9 @ 20	902				
	25.2	VK510	9 @ 20	1014				
35 ft.	14.0	VK500	12 @ 75	1454		NO FM APPROVALS FOR UPRIGHT SPRINKLERS		
	16.8	VK503	12 @ 52	1454				
	22.4	VK506	12 @ 29	1448				
	25.2	VK510	12 @ 23	1087				
40 ft.	14.0	VK500	12 @ 75	1454				
	16.8	VK503	12 @ 52	1454				
	22.4	VK506	9 @ 50	1425				
	25.2	VK510	9 @ 40	1434				

Scenario 2

The following table shows the various Viking quick response sprinklers and the base system demands for the protection of Cartoned Expanded Plastics in an Open-Rack Arrangement at ceiling heights 30 ft. and above.

Table 12

CEP Open-Rack Storage

CEP Open-Rack Storage								
			Pendent			Upright		
Max. Ceiling Height	**K-Factor**	**SIN**	**Design**	**Flow**		**SIN**	**Design**	**Flow**
30 ft.	14.0	VK500	12 @ 50	1484	NO FM APPROVALS FOR UPRIGHT SPRINKLERS			
	16.8	VK503	12 @ 35	1490				
	22.4	VK506	12 @ 25	1583				
	25.2	VK510	12 @ 20	1593				
40 ft.	22.4	VK506	12 @ 75	2327				
	25.2	VK510	12 @ 60	2342				

Scenario 3

The following table shows the various Viking quick response sprinklers and the base system demands for the protection of Uncartoned Unexpanded Plastics in an Open-Rack Arrangement at ceiling heights 30 ft. and above.

Table 13

UUP Open-Rack Storage

UUP Open-Rack Storage								
			Pendent			Upright		
Max. Ceiling Height	**K-Factor**	**SIN**	**Design**	**Flow**		**SIN**	**Design**	**Flow**
30 ft.	14.0	VK500	15 @ 50	1484		NO FM APPROVALS FOR UPRIGHT SPRINKLERS		
	16.8	VK503	15 @ 35	1490				
	22.4	VK506	10 @ 50	1583				
	25.2	VK510	10 @ 40	1593				
40 ft.	22.4	VK506	12 @ 75	2327				
	25.2	VK510	12 @ 60	2342				

Scenario 4

The following table shows the various Viking quick response sprinklers and the base system demands for the protection of Uncartoned Expanded Plastics in an Open-Rack Arrangement at ceiling heights 30 ft. and above.

Table 14

UEP Open-Rack Storage

UEP Open-Rack Storage								
			Pendent			Upright		
Max. Ceiling Height	K-Factor	SIN	Design	Flow		SIN	Design	Flow
30 ft.	14.0	VK500	12 @ 100	1680	NO FM APPROVALS FOR UPRIGHT SPRINKLERS			
	16.8	VK503	12 @ 70	1687				
	22.4	VK506	12 @ 50	1900				
	25.2	VK510	12 @ 40	1913				
40 ft.	25.2	VK510	20 @ 75	4364				

Scenarios 5, 6 and 7

These scenarios involve open-rack storage of uncartoned batteries (Scenario 5), storage over 40 ft. (Scenario 6) and/or storage of batteries with greater than 60% state of charge (Scenario 7).

Protection for these scenarios is based on the hazard classification of the surrounding occupancy and the configuration of the storage; open frame or bin-box/enclosed chamber. Again, the ceiling sprinkler selection for these areas consists of any Viking commercial sprinkler capable of delivering the density at a reasonable pressure and, if the batteries are positioned in racks similar to open-rack storage, then FM Approved in-rack sprinklers would be required. Unlike previous guidance, FMDS 7-112 does not establish a minimum K-factor for in-rack sprinklers. Viking has numerous K5.6 and K8.0 sprinklers that are FM Approved for in-rack use. FMDS 7-112 sets a minimum operating pressure of 7 psi for these sprinklers and a minimum pressure of 10 psi for K11.2 sprinklers.

Table 15

FM Approved Viking Storage Sprinkler Line-up – In-Rack Sprinklers

K5.6	VK1021, VK3021, VK550, VK556
K8.0	VK2021, VK3521, VK560, VK566
K11.2	VK377, VK536, VK553, VK554
K14.0	VK500
K16.8	VK503

Conclusions

Tests have been conducted at the module level to evaluate the performance of different fire suppressants such as water, wet chemical and dry chemical. The tests concluded that water was the most effective fire suppressant.

Factory Mutual does not have any special approvals for sprinklers protecting Lithium-ion cells or modules but does contain specific guidance on how systems are designed and supplied.

Viking has FM Approved sprinklers that can meet all design requirements in FMDS 7-112 and FMDS 8-9.