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Sprinkler Protection for Parking Structures

The Impact of Hazard Classification Changes & Evolving Challenges

The National Fire Protection Association (NFPA) has recognized the potential hazards in garages and parking structures since 1927. During that time, manufacturers like Ford, LaSalle, Studebaker and Rickenbacker were building automobiles almost entirely of steel, including fuel tanks. Even with the presence of combustible fuel in the tanks, the resulting fire hazard was relatively low.

There was minimal change in the construction of automobiles and subsequently, the fire hazards presented, for over fifty years. Since the 1980s however, there have been two major areas of development that have increased the potential fire hazard presented by automobiles: plastics and fuels.

In every aspect of life, there has been a steady increase in the use of plastic materials and the automobile industry is no exception. While theoretically reducing weight and increasing gas economy, plastic materials, mainly polypropylene, polyurethane and polyvinylchloride (PVC) also increase the potential fuel load and heat release rate in the event of a fire. In addition, fuel tanks of high-density polyethylene (HDPE) have replaced metal fuel tanks and introduced a potential failure point resulting in combustible liquid spills which, when ignited, could turn into running pool fires igniting other vehicles and result in a rapidly growing fire.

There have also been developments in the use of fuels other than gasoline and diesel. The so-called "alternative fuels" are becoming more and more common. These alternative energy sources include lithium-ion batteries, solid-state lithium batteries, hydrogen fuel cells and liquified natural gas (LNG).

Lithium-ion batteries can be compromised through thermal, electrical or mechanical malfunction or damage. This may release the battery's combustible electrolyte, leading to "thermal runaway," a chain reaction that spreads to other cells and is impossible to stop without physical containment or constant cooling with water.

The main hazard of a hydrogen fuel cell vehicle is the rupture of the hydrogen storage tank and the release of the gas. As hydrogen is much lighter than air, leaking or burning hydrogen would quickly travel upwards in a column, as opposed to a gasoline-fueled car, where the spilled fuel gathers underneath the car.[1]

Parking Structure Construction

As with the automobile, there have been changes in parking structures. The size and configuration of parking structures will vary widely based on the environment in which they are located but the ultimate goal is the same; get as many cars as possible in the space. For example, parking structures attached to airports, malls or sporting venues tend to be very large multilevel open structures with each level consisting of multiple acres of space.

Inner-city parking garages tend to be limited in size to the property or building in which they are located. The limited area of these enclosed multi-level garage designs has led to the use of vehicle stacking systems to increase parking capacity.

Car Stackers

Car stackers, located in parking structures, are restricted by the ceiling height of the parking level which typically limits the stacker to only two cars. Car stackers that are placed in larger buildings with higher ceilings, like warehouses, can be four or five cars high, but the design is basically the same. The car enters the individual lift module and is raised, allowing for another vehicle to come in below it.

There are multiple challenges presented to a fire sprinkler system by car stackers. First and foremost is the combination of increased density of fuel with a more efficient means of fire growth and a combination of obstruction to sprinkler spray pattern development and shielding of the fire from sprinkler spray.

The Evolution of the Protection Guidance

NFPA 88A Parking Structures

NFPA first recognized the potential fire risk in parking structures, but it would take thirty years before NFPA would publish a standard for parking structures; NFPA 88, *Standard for Garages* was adopted in 1957. In 1973, the standard was divided into two documents: NFPA 88A, *Standard for Parking Structures* and NFPA 88B *Standard for Repair Garages*. At that point, NFPA 88A included requirements for sprinklers, but only in underground or enclosed parking structures. In 1998, the technical committee added language to clarify that automatic sprinklers were not required in open parking structures.

This language remained in the standard for 25 years until the 2023 edition reversed course and now requires fire sprinklers in all parking structures.

NFPA 13 Installation of Sprinkler Systems

Since the original publication of NFPA 88A, it has referenced NFPA 13 for fire sprinkler installation.

Beginning with the 1976 edition, all the way up to the 2019 edition, NFPA 13 identified parking structures as *Ordinary Hazard Group 1*, which requires a design density of 0.15gpm/1500 ft^2.

In 2016, the technical committee responded, increasing use of car stackers in parking garages by classifying them as *Extra Hazard Group 1* which is defined as "occupancies or portions of other occupancies where the quantity and combustibility of contents are very high introducing the probability of rapidly developing fires with high rates of heat release but with little or no combustible or flammable liquids". The design density for these occupancies is 0.3gpm/2500 ft^2.

Recognizing the results of research and in response to actual parking structure fires, the technical committee changed the hazard classification of parking structures to *Ordinary Hazard Group 2* in the 2022 edition. This increased the design density change to 0.2gpm/1500 ft^2.

The committee also recognized that parking structures with car stackers contained moderate to substantial amounts of flammable or combustible liquids and the automobiles and the stackers themselves provided extensive shielding of combustibles from the sprinkler spray. This resulted in the reclassification of park structures with car stackers to *Extra Hazard Group 2* in the 2022 edition. Thus, the design density for these occupancies increased to 0.4gpm/2500 ft^2. It is important to note that the standard only provides design density which would come from ceiling sprinklers. This requirement may only be effective in a parking structure with a two-car stacker system where there is only one level that would provide shielding. There is no guidance provided on spacing, clearances or obstructions for designing sprinkler systems within a multi-level automated stacking system.

Figure 1 and *Figure 2* detail the Viking sprinklers that are appropriate for parking structures along with the resulting theoretical design demand for wet and dry ceiling systems designed to NFPA 13.

Figure 1

Viking Sprinklers in NFPA 13 OH2 & EH2 Design Demands - Wet System

Parking Structure Sprinkler Protection - NFPA 13

SIN	Type	K-Factor	Sprinkler Spacing (ft^2)	Sprinkler Coverage	Density	Minimum Pressure (psi)	Flow (gpm)	Wet System Area (ft^2)	Number of Sprinklers	System Demand (gpm)
Standard Parking Structure (OH2)										
VK3001	SSU	5.6	10x13	130	0.2	21.6	29	1500	12	335
VK351	SSU	8.0	10x13	130	0.2	10.6	26	1500	12	300
VK530	SSU	11.2	10x13	130	0.2	7.0	30	1500	12	346
VK580	SSU	16.8	10x13	130	0.2	7.0	44	1500	12	508
VK532	ECOH	11.2	12x12	144	0.2	12.1	30	1500	11	330
			14x14	196	0.2	12.1	30	1500	8	230
			16x16	256	0.2	20.7	51	1500	6	299
			18x18	324	0.2	33.7	65	1500	5	301
			20x20	400	0.2	51.0	80	1500	4	300
VK570	ECOH	14.0	12x12	144	0.2	7.8	39	1500	14	546
			14x14	196	0.2	7.8	39	1500	10	390
			16x16	256	0.2	13.3	51	1500	8	408
			18x18	324	0.2	21.6	65	1500	7	455
			20x20	400	0.2	32.7	80	1500	5	400
Car Stackers - 2 Levels (EH2)										
VK530	SSU	11.2	10x10	100	0.4	12.8	40	2500	25	1000
VK580	SSU	16.8	10x10	100	0.4	7.0	45	2500	25	1125
VK595	EC	25.2	14x14	196	[0.6]	22.0	118	2500	13	1505
			15x9	144	[0.8]	22.0	118	2500	18	2124

Figure 2

Viking Sprinklers in NFPA 13 OH2 & EH2 Design Demands - Dry System

Parking Structure Sprinkler Protection - NFPA 13

SIN	Type	K-Factor	Sprinkler Spacing (ft^2)	Sprinkler Coverage	Density	Minimum Pressure (psi)	Flow (gpm)	Dry System Area (ft^2)	Number of Sprinklers	System Demand (gpm)
Standard Parking Structure (OH2)										
VK3001	SSU	5.6	10x13	130	0.2	21.6	29	1950	15	435
VK351	SSU	8.0	10x13	130	0.2	10.6	26	1950	15	390
VK530	SSU	11.2	10x13	130	0.2	7.0	30	1950	15	450
VK580	SSU	16.8	10x13	130	0.2	7.0	44	1950	15	660
VK532	ECOH	11.2	12x12	144	0.2	12.1	30	1950	14	420
			14x14	196	0.2	12.1	30	1950	10	300
			16x16	256	0.2	20.7	51	1950	8	408
			18x18	324	0.2	33.7	65	1950	7	455
			20x20	400	0.2	51.0	80	1950	5	400
VK570	ECOH	14.0	12x12	144	0.2	7.8	39	1950	14	546
			14x14	196	0.2	7.8	39	1950	10	390
			16x16	256	0.2	13.3	51	1950	8	408
			18x18	324	0.2	21.6	65	1950	7	455
			20x20	400	0.2	32.7	80	1950	5	400
Car Stackers - 2 Levels (EH2)										
VK530	SSU	11.2	10x10	100	0.4	12.8	40	3250	33	1320
VK580	SSU	16.8	10x10	100	0.4	7.0	45	3250	33	1485
VK595	EC	25.2	14x14	196	[0.6]	22.0	118	3250	17	1957
			15x9	144	[0.8]	22.0	118	3250	23	2663

Sidewall sprinklers are not listed for *EH2 Hazards*. However, NFPA 13 (2022 edition) added language that permits their use in car stackers and car lift systems with sprinklers placed under each level.

When it is possible to install sidewall sprinklers under each level of cars, the ceiling sprinkler system design would revert to *Ordinary Hazard Group 2* as that is the hazard classification of parking garages.

It is important to note that there is no standardized design or installation of car stackers or lift systems. Therefore, there is no standardized design to protect them. Sidewall sprinklers will not be appropriate for all car stackers or car lift systems. In these cases, the sidewall sprinklers must be installed meeting the installation requirements in NFPA 13. However, it is possible to apply a performance-based design and submit it as equivalent to NFPA 13.

FMDS 7-15 Garages

The scope of FMDS 7-15 states that the recommendations apply to garages with either internal combustion engines or electric vehicles parked in them and garages with electric vehicle charging stations.

The protection recommendations are to provide automatic sprinklers for a *Hazard Category 3* (HC-3) occupancy in accordance with Data Sheet 3-26, *Fire Protection for Nonstorage Properties*.

FMDS 3-26 Fire Protection for Nonstorage Occupancies

FMDS 3-26 provides the sprinkler design demands based on a hazard category (HC-1, HC-2, HC-3). Each category has a different demand based on ceiling height and type of sprinkler system (wet or dry).

As noted in FMDS 7-15, parking garages fall into the category of HC-3 area, which tend to have continuously heavier combustible loading as well as limited quantities of ignitable liquids and/or heavier amounts of plastics. With the current construction of automobiles, this would be an accurate description of the hazard. *Figure 3* below is extracted from *Table 2.3.1.10 Sprinkler Design Demands for Hazard Categories*. Because standard parking garages have ceiling heights below 30 ft., only the first column would be applicable.

Figure 3

Extract from FMDS 3-26 Table 2.3.1.10 Sprinkler Design Demands for HC3

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

While there is no specific guidance provided for parking garages with car stackers or automated parking systems, the sprinkler protection in *Table 2.3.1.10* is based on increasing ceiling heights and therefore it may apply to HC-3 occupancies based on ceiling height in *Table 2.3.1.10*. It may be appropriate to consider those densities and resulting system design demands.

Figure 4 and *Figure 5* detail the Viking sprinklers that are appropriate for parking structures along with the resulting theoretical design demand for wet and dry systems designed to FMDS 3-26.

Figure 4

Viking Sprinklers in FMDS 3-26 HC3 design demands - Wet System

Parking Structure Sprinkler Protection - FMDS 3-26

SIN	Type	K-Factor	Sprinkler Spacing (ft^2)	Sprinkler Coverage	Density	Minimum Pressure (psi)	Flow (gpm)	Wet System Area (ft^2)	Number of Sprinklers	System Demand (gpm)
Standard Parking Structure (HC3)										
VK3001	SSU	5.6	10x13	130	0.3	48.5	39	2500	20	780
VK351	SSU	8.0	10x13	130	0.3	23.8	39	2500	20	780
VK530	SSU	11.2	10x13	130	0.3	12.1	39	2500	20	780
VK580	SSU	16.8	10x13	130	0.3	7.0	44	2500	20	880
VK532	ECOH	11.2	16x16	256	0.3	46.0	76	2500	10	742
			18x18	324	0.3	75.0	97	2500	8	748
			20x20	400	0.3	114.8	120	2500	6	750
Car Stackers - 2 Levels (HC3)										
VK530	SSU	11.2	10x10	100	0.3	7.2	30	2500	25	750
VK580	SSU	16.8	10x10	100	0.3	7.0	44	2500	25	1100
VK598	SSU	25.2	10x10	100	0.3	7.0	67	2500	25	2211
VK595	EC	25.2	14x14	196	[0.6]	22.0	118	2500	13	1505
			15x9	144	[0.8]	22.0	118	2500	17	2049

Figure 5

Viking Sprinklers in FMDS 3-26 HC3 design demands - Dry System

Parking Structure Sprinkler Protection - FMDS 3-26

SIN	Type	K-Factor	Sprinkler Spacing (ft^2)	Sprinkler Coverage	Density	Minimum Pressure (psi)	Flow (gpm)	Dry System Area (ft^2)	Number of Sprinklers	System Demand (gpm)
Standard Parking Structure (HC3)										
VK3001	SSU	5.6	10x13	130	0.3	48.5	39	3500	27	1053
VK351	SSU	8.0	10x13	130	0.3	23.8	39	3500	27	1053
VK530	SSU	11.2	10x13	130	0.3	12.1	39	3500	27	1053
VK580	SSU	16.8	10x13	130	0.3	7.0	44	3500	27	1188
VK532	ECOH	11.2	16x16	256	0.3	46.0	76	3500	14	1064
			18x18	324	0.3	75.0	97	3500	11	1067
			20x20	400	0.3	114.8	120	3500	9	1080
Car Stackers - 2 Levels (HC3)										
VK530	SSU	11.2	10x10	100	0.3	7.2	30	3500	35	1050
VK580	SSU	16.8	10x10	100	0.3	7.0	44	3500	35	1540
VK598	SSU	25.2	10x10	100	0.3	7.0	67	3500	35	2211
VK595	EC	25.2	14x14	196	[0.6]	22.0	118	3500	18	2107
			15x9	144	[0.8]	22.0	118	3500	24	2868

The Variations on Fire Sprinkler System Design

Figure 6 shows the applicability of guidance documents and the variation of fire sprinkler system design demands for five parking structure protection scenarios.

Figure 6

System Design Demand Variations

Scenario	Description	NFPA 13 Design Density	FMDS 3-26 Design Density
1	Enclosed Parking Structure, 12ft ceiling, Unobstructed, Wet System	0.2/1500	0.3/2500
2	Open Parking Structure, 12ft ceiling, Unobstructed, Dry System	0.2/1950	0.3/3500
3	Enclosed Parking Structure w/2-car stackers, 15ft ceiling, Unobstructed, Wet System	0.4/2500	0.3/2500
4	Open Parking Structure w/3-car stackers, 30ft ceiling, Unobstructed, Dry System	NA	0.3/3500
5	Enclosed Parking Structure w/4-car stackers, 40ft ceiling, Unobstructed, Wet System	NA	0.3/3600

Evolving Issues

Like all other storage occupancies, parking structures continue to evolve with new technologies that are intended to improve efficiency and convenience. And like other storage occupancies, fire protection is trying to keep pace to provide safety for occupants and integrity for the structure.

Automated Parking Structures

An automated parking system is a multi-level mechanical system that lifts and retrieves cars from an individual parking platform. Unlike traditional parking structures, there is no barrier between each level and no limit to the height. It is basically an open-rack storage of automobiles with an automatic retrieval system.

Because of the unique design of each of these structures, there is no standardized design scheme that can be applied. Each structure and automated parking system must be evaluated individually, and a fire sprinkler system will be uniquely designed and engineered for the challenge presented.

Electric Vehicles (EVs)

When designing for electric vehicles (EVs), two primary questions arise: First, "What is the possibility of a fire while the vehicle is charging?" and second, "Where is the optimal location to position these vehicles to ensure maximum protection in the event of a fire?"

The present consensus is that EVs charging spots should be located at grade level only to aid in manual firefighting, the parking structure should be protected with fire sprinklers and finally, there should be an accessible emergency power shut-off button to manually shut down power to EV chargers.

Energy Storage Systems that power the charging stations should not be overlooked. For these NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems* must be consulted. NFPA 855 states "that when approved by the AHJ, an ESS shall be permitted to be installed in open parking garages without the protection of an automatic fire suppression system where fire, explosion, and fault condition testing documents the system does not present an exposure hazard to parked vehicles when installed in accordance with manufacturer's instructions and this standard."

Alternative Fuel Development

The number of EVs on the road around the world has increased in the last few years representing almost 4%. While this is still a low in percentage of total sales, the rate of sales is rising dramatically, nearly doubling in recent years. Hydrogen fuel cell vehicles are currently less developed and are mainly still in the research stage, with a few thousand sold and refueling stations limited to a few test areas, but this could change as the technology continues to develop.

Lithium-ion batteries that provide the power for EVs can be compromised through thermal, electrical or mechanical malfunction or damage. This damage may release the combustible electrolyte contained in the battery that may result in a phenomenon known as thermal runaway which can impact other cells in a continuous chain reaction that is impossible to stop without physical containment or constant application of water to cool exposed cells.

The main hazard of a hydrogen fuel cell vehicle is the rupture of the hydrogen storage tank and the release of the gas. As hydrogen is much lighter than air, leaking or burning hydrogen would quickly travel upwards in a column, as opposed to a gasoline-fueled car where the spilled fuel gathers underneath the car.[1]

Updating and Retrofitting Sprinkler Systems

Automobiles parked in buildings, once a relatively benign hazard, has evolved into a significant threat to building structures and life safety. New developments in automobile technologies and combustible automobile components have resulted in changes to the standards governing the protection of parking structures from fire. These changes have resulted in structures that may be woefully under-protected. And while it is not the intent of the standards to be retroactively applied, changes in the fire hazard within a building should at the very least trigger an analysis of the new hazard and the determination if a sprinkler system installation or upgrade is necessary.

Re-evaluating an existing system is of critical importance given the heat release rate from these fires and the structural damage, like spalling of concrete and weakening steel structures that can result.

Consider a system that was designed under the 2010 edition of NFPA 13 as an OH1 (0.15gpm/sq.ft). The 2022 edition would require a system design as an OH2 (0.2gpm/sq.ft.) which is more than a 30 percent increase in demand.

Worse than that, is the possibility that car stackers have been retroactively installed into a structure with a system designed for the 2010 edition. With the new hazard classification of EH2, the system demand increases by almost 400 percent.

It is understood that the standard is not designed to be retroactively applied, but there is a documented NEW hazard present, and the system may not be capable of controlling a fire in this new situation. Is it truly good fire protection practice not to recommend system upgrades in the face of a substantial change in the hazard?

Sources

FMDS 2-0 – *Installation Guidelines for Automatic Sprinklers*

FMDS 3-26 – *Fire Protection of Nonstorage Occupancies*

FMDS 7-15 – *Garages*

NFPA 13 – *Standard for the Installation of Sprinkler Systems*

NFPA 88A – *Standard for Parking Structures*

Classification of Modern Vehicle Hazards in Parking Structures and Systems; Fire Protection Research Foundation, Phase 2, May 2024

Footnotes

1. Boehmer, Haavard; Klassen, Michael; Olenik, Stephen – "Modern Vehicle Hazards in Parking Structures and Vehicle Carriers" Final Report, Fire Protection Research Foundation / July 2020