

Fire Protection and Manual Firefighting methods for the AutoStore system

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PRODUCT COMPLIANCE



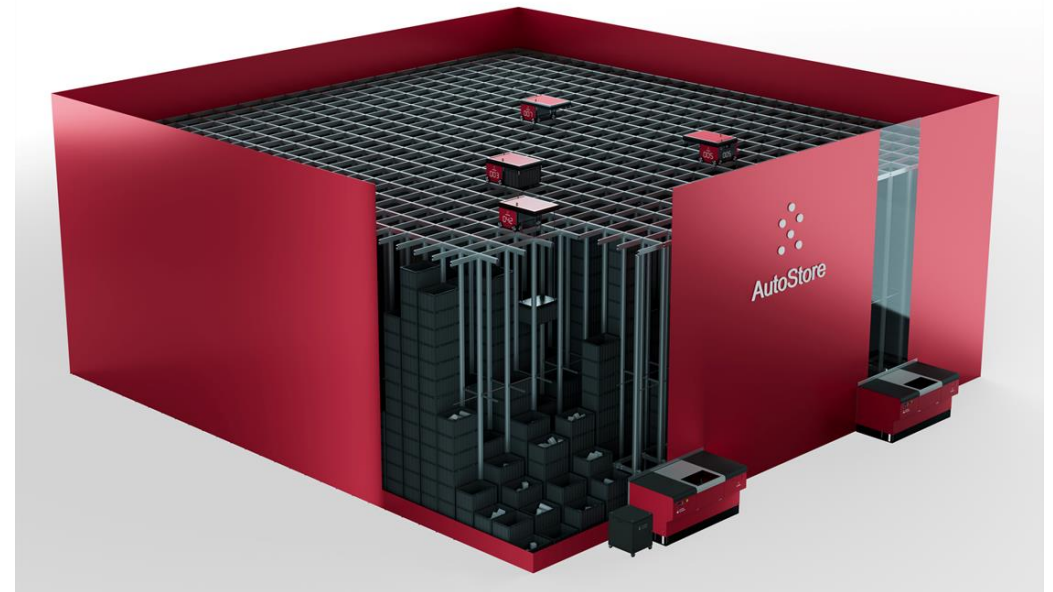
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AutoStore | What is AutoStore?

In the 90's, we were the largest distributor of electric components in Northern Europe. We built a big new warehouse, but it was full of inventory within the first month. Instead of building another warehouse, Technical Director Ingvar Hognaland had an idea that resulted in the game-changing Cube Storage Automation system.

For over 20 years AutoStore™ has continued to innovate and improve its system for its customers.

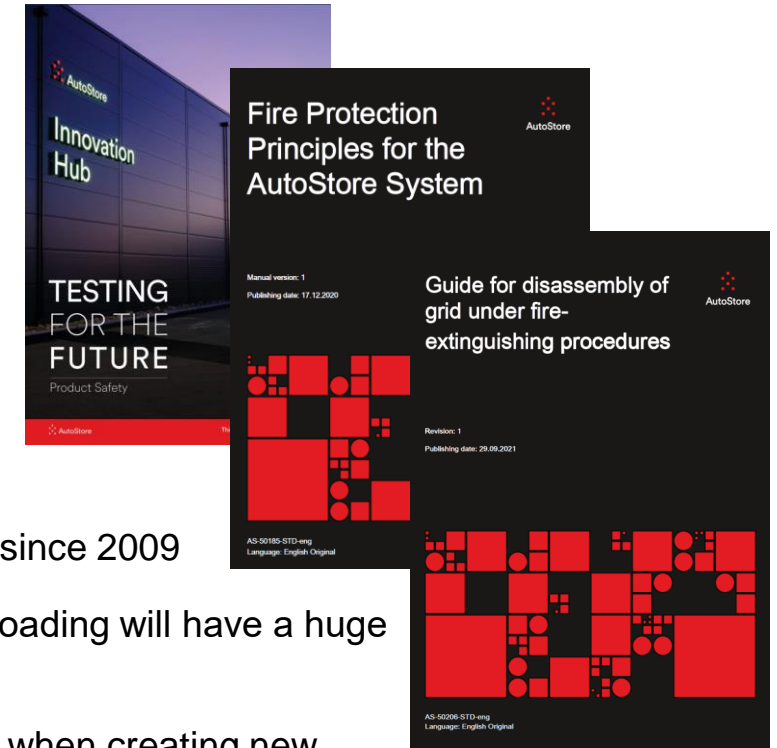
AutoStore has more than 850 systems across 45 countries



AutoStore | Product Safety and Fire Safety

AutoStore has a relentless focus Product Safety, among other:

- Electrical Safety
- Fire Safety
- Seismic
- Machine Safety



AutoStore has performed over 100 individual small-, intermediate-, and large-scale fire tests since 2009

AutoStore’s scientific approach to fire testing show that there are several properties in a top loading will have a huge impact on fire growth and heat release during a fire.

Our design focuses on minimizing the fire hazards. All experience is taken into consideration when creating new products or recommendation of a specific strategy to protect our system.

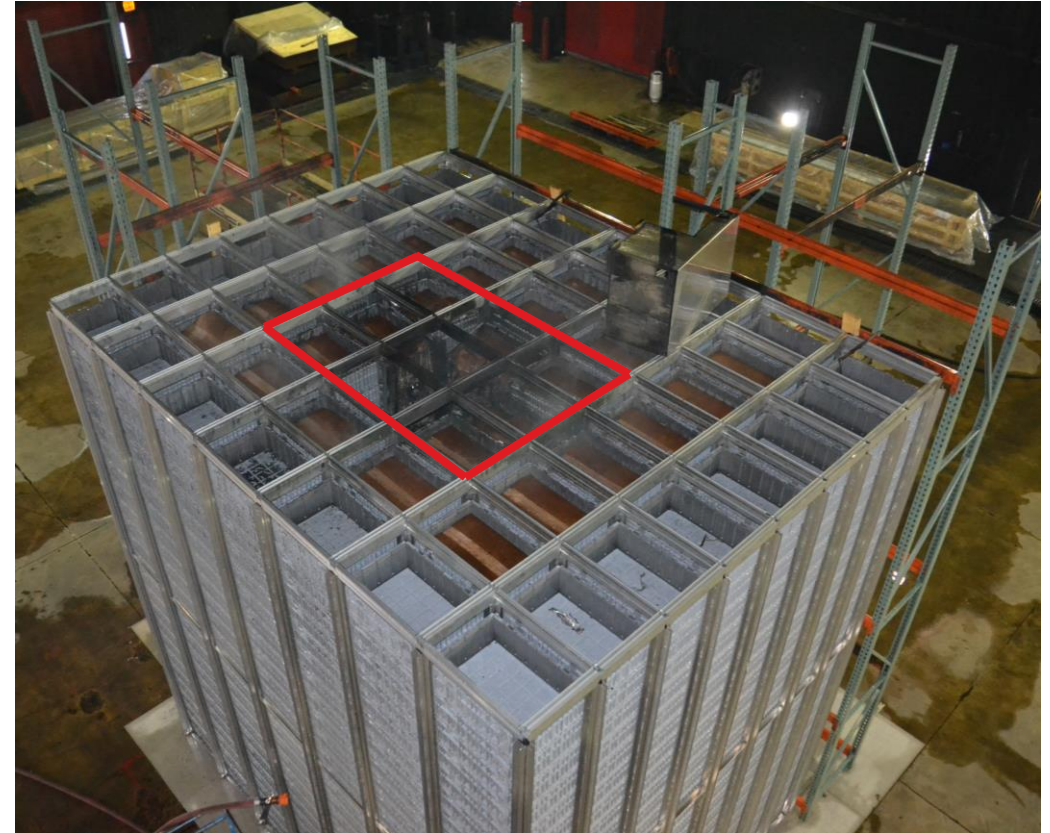
AutoStore makes a significant efforts in limiting the probability of a fire starting in the first place and is the industry leader in fire safety and testing.

Our research indicate that a fire will most likely start outside the AutoStore bins. There are no electrical systems or sources of ignition inside the AutoStore bins based on the commodities stored.

AutoStore | Fire test - Vertical growth - Limited Horizontal Fire Damage

Rapid vertical growth = rapid sprinkler release and suppression

Same grid – damage mainly limited to a 3 x 3 cell area



UL - Final Report - Project 4787818459 - ESFR Test - March 20_2017

AutoStore | Fire Test Summary

DATE	REPORT	DESCRIPTION	DATE	REPORT	DESCRIPTION
Aug. 2009	RISE Research Institute <u>Report:</u> RISE: P903499/Rev.1	Small-scale test - comparing fire characteristics of the primary two plastic compounds, HDPE and PP-ESD, used in AutoStore Bins	Feb. 2016	RISE Research Institute <u>Report:</u> RISE: 5P09926	Small-scale comparison tests to compare the fire characteristics of PP-C with different fire-retardant additive combinations with HDPE
Dec. 2009	RISE Research Institute <u>Report:</u> RISE: P903510	Large-scale test - first series of large-scale tests using a high-expansion foam system	Oct. 2016	RISE Research Institute <u>Report:</u> RISE: 5P05412	Intermediate-scale fire tests comparing AutoStore Bin designs
Sept. 2009	RISE Research Institute <u>Report:</u> RISE: P904143	Large-scale test - second series of large-scale tests using a high-expansion foam system	Oct. 2016	RISE Research Institute <u>Report:</u> RISE: 6P02895	Two pre-tests of Early Suppression Fast Response (ESFR) sprinkler conducted using the combination of parameters that had proven to be the most severe in the intermediate-scale fire tests
Mar. 2010	RISE Research Institute <u>Report:</u> RISE: PX00778	Small-scale test - 2 alternative HDPE and PP-ESD plastic compounds tested & compared to earlier tests in project P903499	Mar. 2017	Underwriters Laboratories, Inc. <u>Report:</u> UL: 4787818459, NC13069	Four large-scale tests of Early Suppression Fast Response (ESFR) sprinkler verification tests
Apr. 2010	RISE Research Institute <u>Report:</u> RISE: P907897	Large-scale tests - free-burn fire tests of fire growth rate during initial phase of a fire in a representative section of a system	Feb. 2018	RISE Research Institute <u>Report:</u> RISE: 7P07649	Medium-scale tests of Influence on fire suppression performance using Bins with lids
Mar. 2011	RISE Research Institute <u>Report:</u> RISE: PX10701	Ignitability tests according to UL 94, "Standard for Safety of Flammability of Plastic Materials for Parts in Devices & Appliances	May 2019	RISE Research Institute <u>Report:</u> RISE: 8P08096	Test to measure the amount of water collected from a representative Early Suppression Fast Response (ESFR) sprinkler that is collected in the top layer of Bins of an AutoStore Grid
Apr. 2011	RISE Research Institute <u>Report:</u> RISE: PX11228	Ignitability tests according to UL 94, "Standard for Safety of Flammability of Plastic Materials for Parts in Devices & Appliances	2018	Wagner Group GmbH	Large-scale fire test of an AutoStore system under reduced oxygen concentration
Jun. 2011	RISE Research Institute <u>Report:</u> RISE: PX12667	Ignitability tests according to UL 94, "Standard for Safety of Flammability of Plastic Materials for Parts in Devices & Appliances	Sept. 2019	RISE Research Institute <u>Report:</u> RISE: 9P03067A	Comparison of HDPE and PP-C Bins with and without drainage holes and final extinguishment tests with medium-expansion foam
2012 - 2013	RISE Research Institute <u>Report:</u> RISE: PX03821-02-01--5	Series of 5 ignitability tests according to IEC 60695-11-5 (2004) and UL 94 (2015)	Sept. 2019	RISE Research Institute <u>Report:</u> RISE: 9P03067B	Summary report on the influence of water drainage holes in AutoStore system Bins
Jun. 2012	Underwriters Laboratories, Inc. <u>Report:</u> UL: 12CA13688, NC 13069	Four large-scale tests of control-mode sprinkler tests were conducted at Underwriters Laboratories, Inc	Mar. 2020	RISE Research Institute <u>Report:</u> RISE: 9P08958	Series of intermediate-scale fire tests were conducted to provide an indication of the fire suppressibility and severity of a fire in H220, H330 and H425 Bins
Oct. 2012	Underwriters Laboratories, Inc. <u>Report:</u> UL: 12CA40286, NC13069	Large-scale test of water distribution tests with upright sprinklers	Feb. 2021	RISE Research Institute <u>Report:</u> RISE: P106771	Intermediate-scale top bin ignition tests with H220, H330 and H425 bins
Feb. 2013	RISE Research Institute <u>Report:</u> RISE: PX27939-1	Series of 3 tests of fire barriers for within the Grid, per VdS CEA 4001en	Feb. 2021	Western Norway University of Applied Sciences (HVL) <u>Report:</u> INERGEN	INERGEN distribution test and fire tests with ignition floor level and top bin
Feb. 2013	RISE Research Institute <u>Report:</u> RISE: PX27939-2	Free-burn fire tests of fire growth rate during the initial phase of a fire in a palletized storage arrangement of the HDPE Bins	May 2021	Underwriters Laboratories, Inc. <u>Report:</u> UL: 4789911434, NC13069	Large Scale Sprinkler tests with the AutoStore system incorporating polypropylene plastic bins with cartoned unexpanded group A plastic commodity including Fire Fighter Response test
Jul. 2014	RISE Research Institute <u>Report:</u> RISE: 4P04364	Small-scale tests of plastic compounds to compare a PP-C and HDPE compounds used for the Bins	Feb 2022	RISE Research Institute <u>Report:</u> RISE: P113643	Small- and intermediate-scale fire test using AutoStore bins filled with glass bottles with fragrant liquid
Oct. 2014	RISE Research Institute <u>Report:</u> RISE: 4P05641	Small-scale tests of plastic compound of PP EL plastic compared to the two different plastic compounds tested and reported in 4P04364	Mar. 2022	Underwriters Laboratories, Inc. <u>Report:</u> UL: 4790300461, NC13069	Large Scale Sprinkler Tests With the AutoStore System Incorporating Polypropylene Plastic Bins With Cartoned Unexpanded Group A Commodity for 30 ft. Tall Ceilings

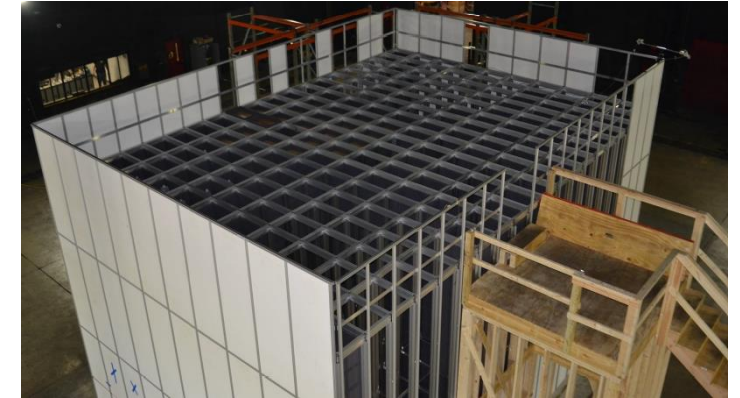


UL test 2021
Manual Firefighting tactical measures
Sprinkler test

AutoStore | UL 2021 - Test Overview

Two main goals of the test:

1. Manual Fire Fighting Methodology Testing and Training Development
2. Sprinkler Performance Testing



Test	Description	Ceiling Height [m]	K-factor [lpm/bar ^{0,5}]	Starting Pressure [bar]
1	Robot Smoke	N/A	N/A	N/A
2	Small Robot Fire	N/A	N/A	N/A
3	Manual Extinguishment / Sprinkler test	7.6	K200	3.45
4	Sprinkler Endurance Test	7.6	K200	3.45
5	Sprinkler Endurance Test	13.7	K360	6.9

Report prepared by Underwriters Laboratories Inc. (Project 4789911434, NC13069) Issued: June 28, 2021

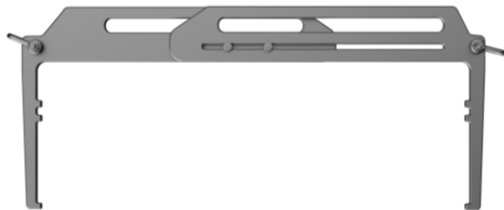
AutoStore | UL 2021 – Manual Firefighting Tools



Firefighter Halligan Tool



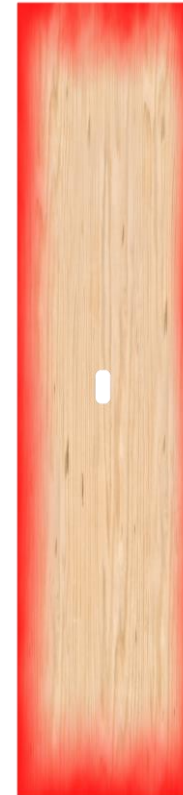
Reciprocating Saw



AutoStore Bin Removal Tool



Pike Pole – 10'



Top-Deck Walking Platform

AutoStore | UL 2021 – Tactical measures

1. Cut MDF panels and column at 2.5 bin height



2. Remove panels and column



3. Cut MDF panels vertically and remove



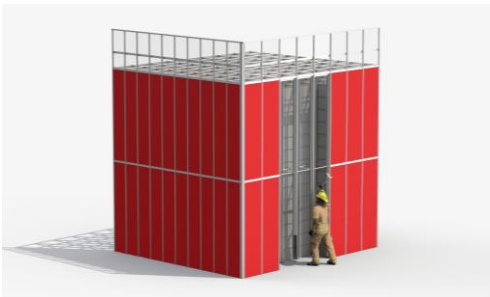
4. Grid ready for bin removal, 3 bins wide



5. Remove bins from grid using the bin removal tool



6. Remove column spacer



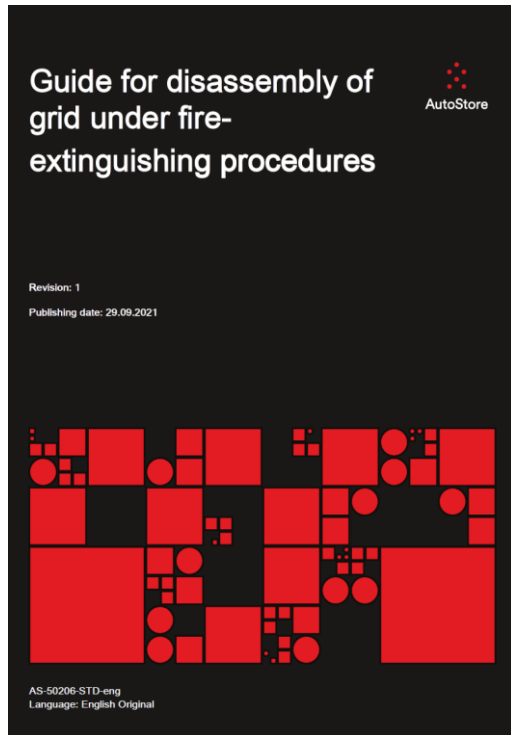
7. Remove column



8. When needed, drain top 3 bins for water using a pike pole



AutoStore | UL 2021 – Tactical measures



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Incident Planning

Prepare and Plan

In a partnership with Underwriters Laboratories Inc. (UL) and their Safety Matter Experts (SMEs), a method was developed for the disassembly of the AutoStore grid during an unwanted event. The procedure is based on available fire truck equipment together with an AutoStore developed Bin removal tool. This video contains an explanation of the procedure, tactical considerations, and feedback from participating firefighters.

Get access to our video



Training video available on the AutoStore website: <https://www.autostoresystem.com/system/product-safety>

AutoStore | UL 2021 – Fire Sprinkler Tests

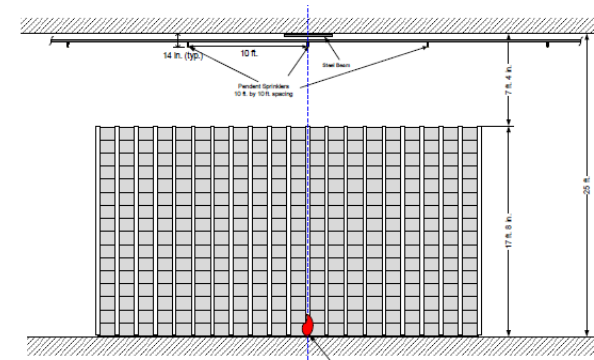
Sprinkler tests:

- Test 4 and 5 had a mock-up robot above the ignition source
- The stack adjacent to the ignition source was 4 bins tall

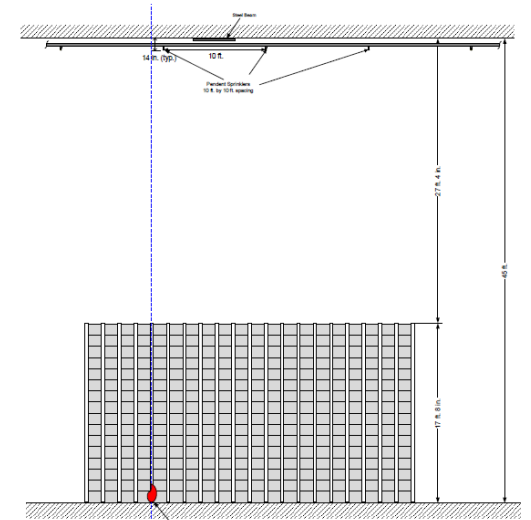
Test Parameters	Test 3	Test 4	Test 5
Storage height [m (ft)]	5,28 (17 ft. 4 in)		
Ceiling height [m (ft)]	7,6 (25')	7,6 (25')	13,7 (45')
Ignition location	Under 1 sprinkler	Between 2 sprinklers	Under 1 sprinkler
K-factor [lpm/bar ^{0,5} (gpm/psig ^{0,5})]	200 (14.0)	200 (14.0)	360 (25.2)
Sprinkler discharge:	Standard	Standard	Declining Density curve
Discharge Density [mm/min (gpm/ft ²)]	36,7 (1,0)	36,7 (1,0)	101,9 (2,5)
Discharge Pressure [bar (psi)]	3,4 (50)	3,4 (50)	6,9 (100)

Full Report: Report prepared by Underwriters Laboratories Inc. (Project 4789911434, NC13069) Issued: June 28, 2021

Ceiling height: 7,6 m (25')



Ceiling height: 13,7 m (45')



AutoStore | UL 2021 – Fire Sprinkler Tests

Test 3

Duration test: 2 hrs 55 min
1. Sprinkler Operate: 7 min
Number of sprinklers: 1



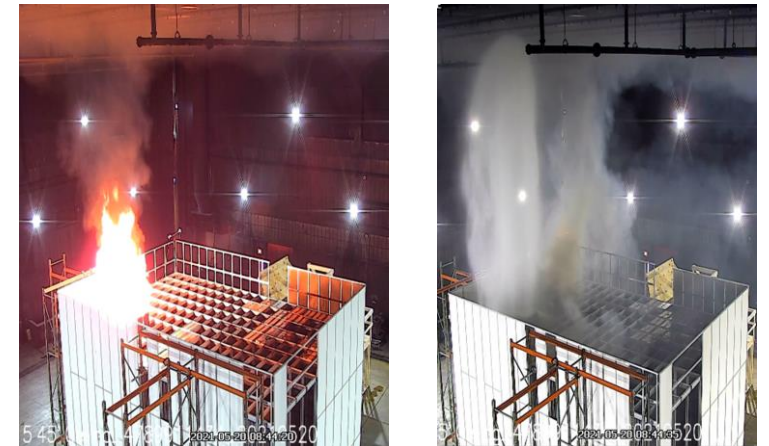
Test 4

Duration test: 2 hrs 4 min
1. Sprinkler Operate: 3 min 25 sec
2. Sprinkler operate: 3 min 39 sec
Number of sprinklers: 2



Test 5

Duration test: 2 hrs 4 min
1. Sprinkler Operate: 3 min 53 sec
Number of sprinklers: 1



AutoStore | UL 2021 - Test Summary

Test 1 – 2

Focus:

- Training

Result:

- Safe to walk out on grid
- Limited damage to MDF



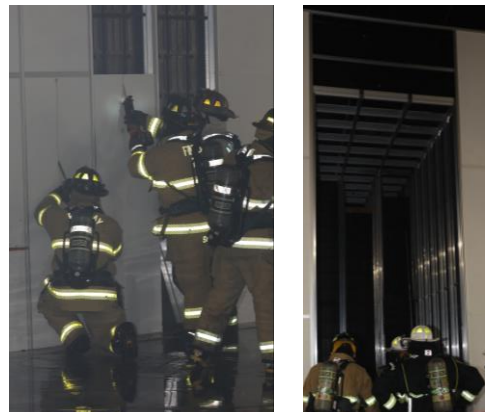
Test 3

Focus:

- Manual fire fighting method validation

Result:

- Sprinkler controlled and suppressed the fire
- Established firefighting tactical measures



Test 4

Focus:

- Sprinkler protection
Ceiling height 25'

Result:

- Fire controlled and suppressed by sprinklers
- Regrew after sprinklers were turned off
- Final extinguishment:
 - 9 min - Sprinklers
 - 12 min - hose streams



Test 5

Focus:

- Sprinkler protection
Ceiling height 45'

Result:

- Final extinguishment achieved by ceiling level sprinkler only
- Temp < 20 °C after 28 min





UL test 2022
Final Extinguishment Ceiling Level Sprinklers

AutoStore | Acknowledgement

The fire tests conducted at Underwriters Laboratories (UL) in Chicago in March 2022 was conducted with the support of FM Global.



AutoStore | UL 2022 – Test Goal

Overall goal: Final Extinguishment Ceiling-Level Sprinklers only

- Final extinguishment with ignition location below 1 sprinkler
- Final extinguishment with ignition location between 4 sprinklers
- Final extinguishment with ignition location between 2 sprinklers
- Ceiling steel temperature should not exceed 538 ° C

AutoStore | UL 2022 – Test Parameters

Grid Size: 8 x 7 Cells (4.0 m x 4.1 m)

Mock-up Robots: 3 Mock-up Robots above three partially filled cells (4 bins high)

Number of bins: 860

Commodity: Unexpanded Cartoned Group A Plastic

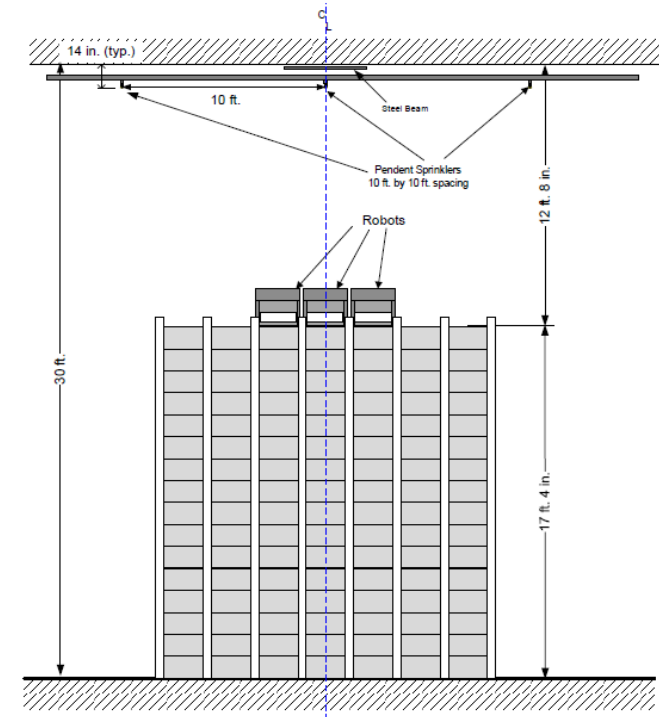
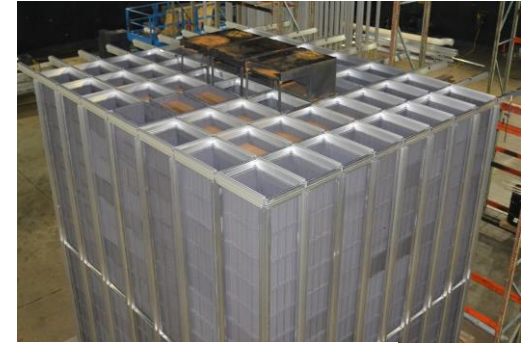


Figure 19 Elevation View of Test Arrangement from the East - Test 2
(Between Two Sprinklers on Separate Branchlines)

AutoStore | UL 2022 – Test Overview

Test Parameters	Test 1	Test 2	Test 3	Test 4
Storage height [m (ft., in.)]	5.3 (17 ft. 4 in.)			
Ceiling height [m (ft)]	9.1 (30')			
Nominal Clearance [m (ft., in.)]	3.5 (11 ft. 6 in.)			
Deflector Distance [mm (in.)]	356 (14)			
Ignition location	Between 4 sprinklers	Between 2 sprinklers	Between 4 sprinklers	Under 1 sprinkler
K-factor [liter/bar ^{0.5} (gpm/psig ^{0.5})]	360 (25.2)			
Discharge Density [mm/m ² (gpm/ft. ²)]	81.5 (2.0)	114.1 (2.8)	114.1 (2.8)	114.1 (2.8)
Discharge Pressure [bar (psig)]	4.5 (65)	8.3 (120)	8.3 (120)	8.3 (120)

AutoStore | UL 2022 – Results Test 1

Ignition Location:	Between 4 sprinklers
Duration test:	2 h 4 min
Number of sprinklers:	2
1. Sprinkler Operate:	5 min
Last Sprinkler operate:	5 min 1 sec
Final Extinguishment Yes/No:	No
Manual efforts needed Yes/No:	Yes

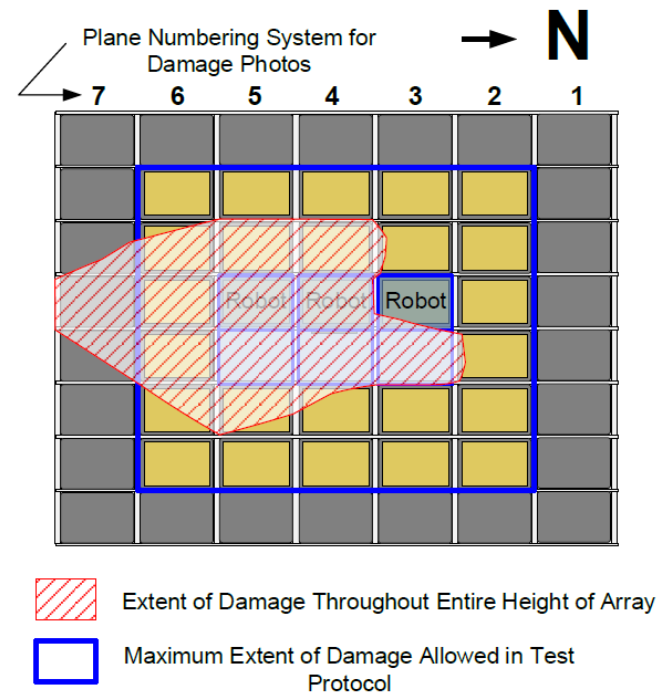
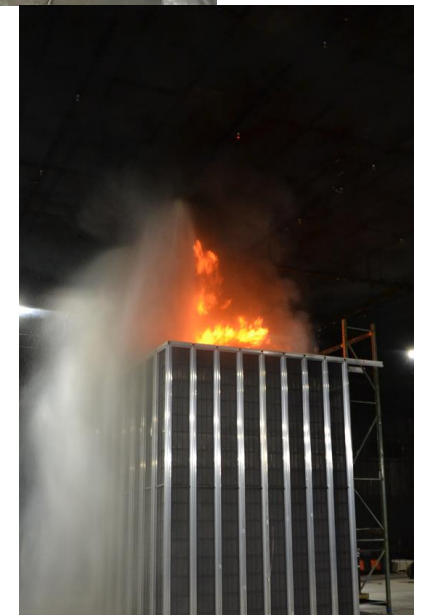


Figure 27 Overall Damage Assessment - Test 1 – Between Four Sprinklers



AutoStore | UL 2022 – Results Test 2

Ignition Location: Between 2 sprinklers

Duration test: 1 h 5 min

Number of sprinklers: 1

1. Sprinkler Operate: 4 min 18 sec

Final Extinguishment Yes/No: Yes

Manual efforts needed Yes/No: No

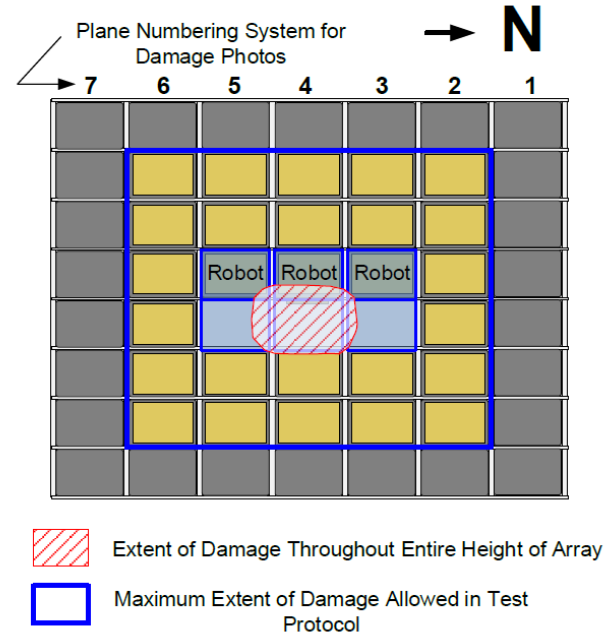


Figure 28 Overall Damage Assessment - Test 2 – Between Two Sprinklers



AutoStore | UL 2022 – Results Test 3

Ignition Location: Between 4 sprinklers

Duration test: 2 h 6 min

Number of sprinklers: 3

1. Sprinkler Operate: 5 min 44 sec

Final Extinguishment Yes/No: Yes

Manual efforts needed Yes/No: No

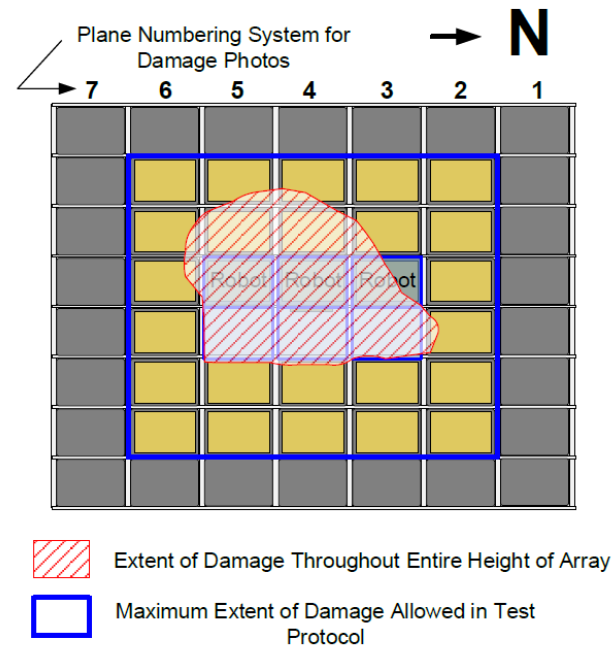
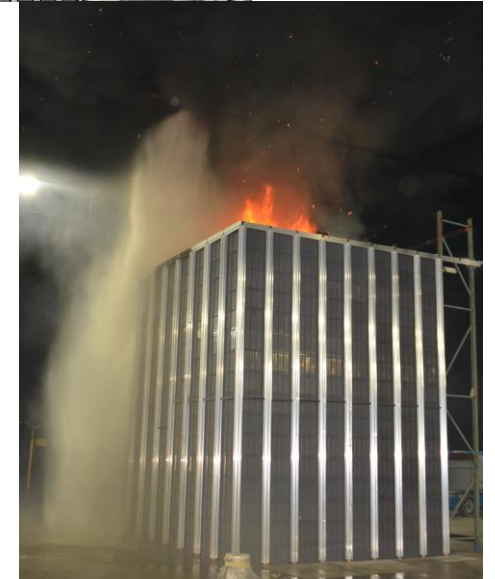


Figure 29 Overall Damage Assessment - Test 3 – Between Four Sprinklers



AutoStore | UL 2022 – Results

Test 4

Ignition Location: Under 1 sprinkler

Duration test: 1 h 5 min

Number of sprinklers: 1

1. Sprinkler Operate: 4 min 28 sec

Final Extinguishment Yes/No: Yes

Manual efforts needed Yes/No: No

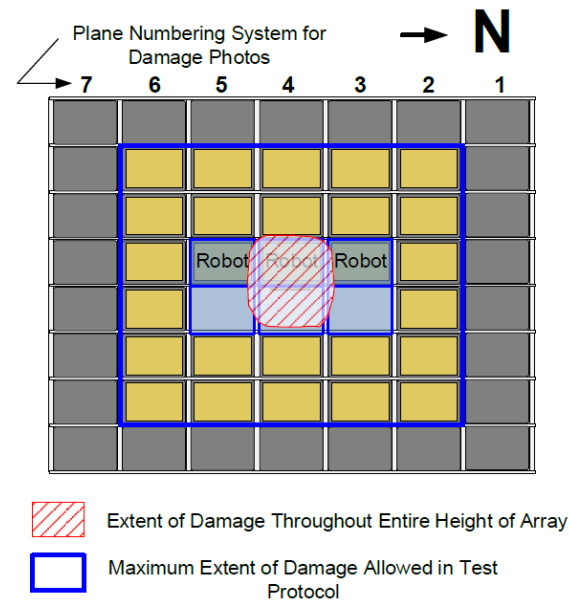


Figure 30 Overall Damage Assessment - Test 4 – Under One Sprinkler



AutoStore | UL 2022 – Summary

Test 1: Pressure at sprinkler 4.5 bar (65 psi). The fire spread outside the damage criteria, and manual fire fighting efforts were used to completely extinguish the fire.

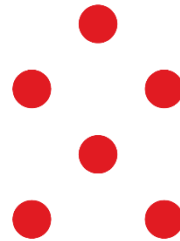
The pressure was increased to 120 psi (8.3 bar), which lead to:

Test 2 – 4: Final extinguishment was achieved with ceiling-level sprinklers only for all three configurations.

There were limited lateral fire spread

And only limited number of sprinkler activated, maximum 3.

All were extinguishment within our time limit of 2 h water duration.



Thank you for your attention!

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