



# AutoStore - Fire Protection, research and testing

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**Product Safety**

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# AutoStore | Where did it all start?





## How it started

In the 90's, we were a very successful electronics component distributor.

As the largest distributor in Northern Europe, we build ourself a new big warehouse to secure our future growth. But after few months it was already full of inventory, and instead of building another expensive warehouse – we were forced to think differently.

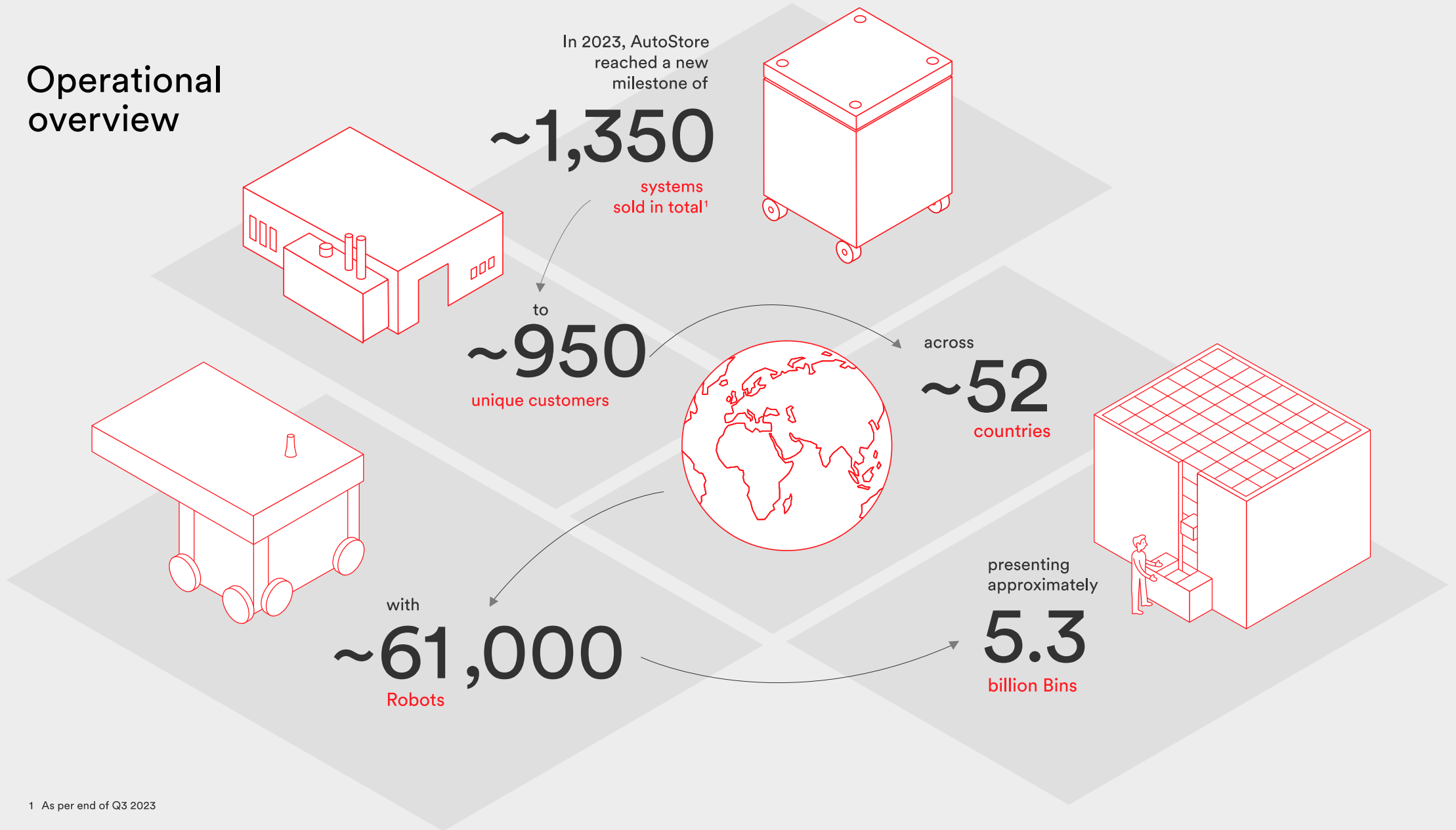
Our Technical Director Ingvar Hognaland came up with the genius idea of removing the most wasteful and expensive component of our warehouse – the areas only filled with air.

That inventive idea resulted in the game-changing Cube Storage Automation system - **AutoStore™**

**For over 20 years we have continued to innovate and improve our system to help our customers all over the world**



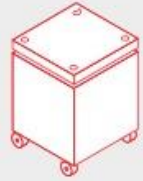
# Operational overview



<sup>1</sup> As per end of Q3 2023

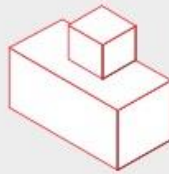
## Product overview

With over 1,250+ systems installed around the world, no two are the same.



### Controller

The Controller is the command center and uses the Router software platform to manage both Bin traffic and the AutoStore database.



### Ports

Ports are workstations where operators pick up or fill in products, tag, pack and send products out. On average, 10 Ports are installed per site.

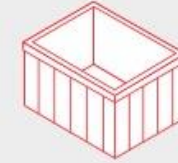
### Grid

The Grid is the aluminum framework that holds the columns of vertically stacked Bins. On average, the Grid is 5.4 meters high and holds 16 levels of 330 mm Bins.



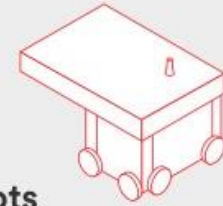
### Bins

Products are stored in Bins, a durable container that holds up to 30 kg of stock. On average, 40,000 Bins are stacked per site. Did you know that one Bin can hold around 100 t-shirts?



### Robots

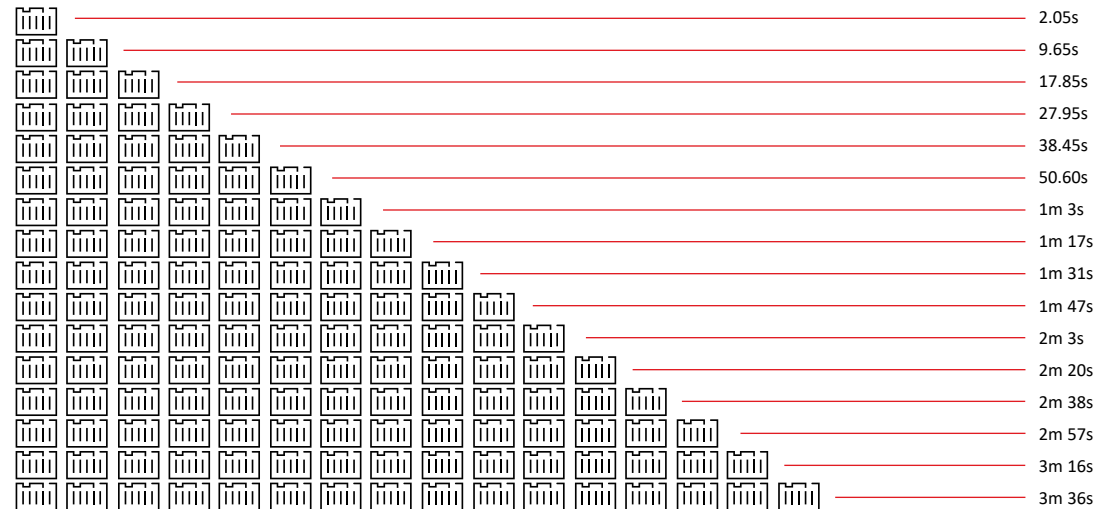
Robots ride on rails along the top of the Grid, retrieving Bins as needed. On average, 45 Robots are in operation per site.



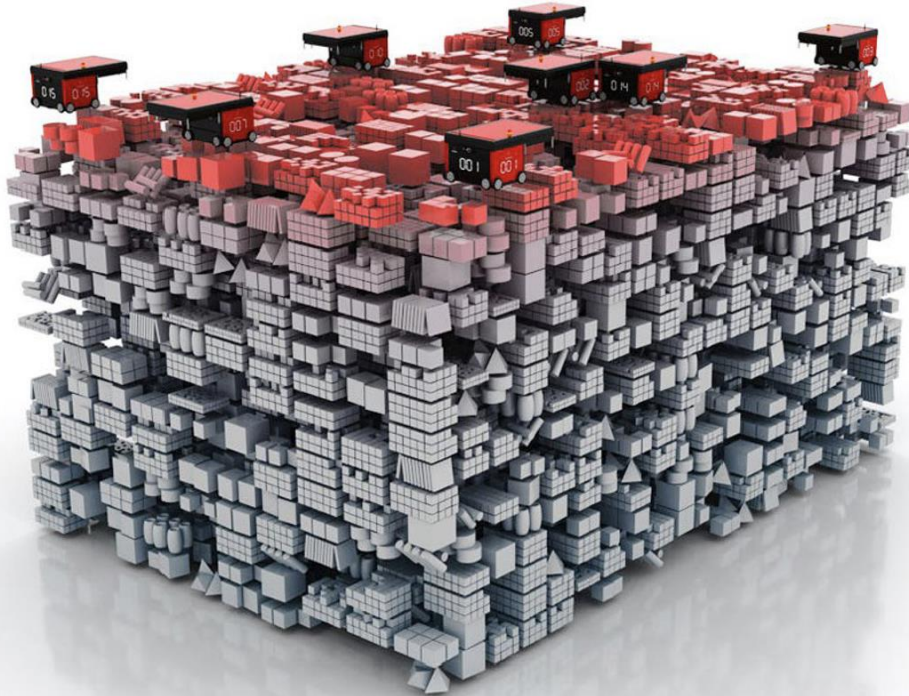


# Bin digging:

- System continuously optimizes the Bin delivery time, making sure the time to complete an order is kept to a minimum
- First time a Bin is needed the robot will “burrow” into the stack and remove the top 15 Bins
- This process takes maximum of 3.5 minutes
- Multiple robots work together in a pack
- Robot lowers Bin to workstation to be fulfilled

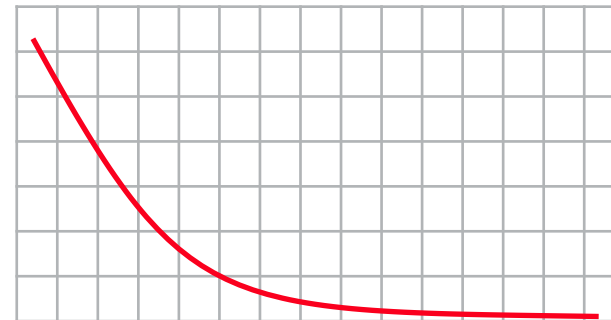


# Natural slotting:



- Active Bins will stay on top as they are always placed there after movement.
- Design philosophy ensures that only on rare occasions will robots have to dig to the bottom of a stack.
- Over time, slower moving Bins will naturally descend to the bottom of stack.
- Pareto Principle: 80% of order lines are associated with 20% of SKU's.

Sales



Products/SKUs

# 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.

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. All experience is taken into consideration when creating new products or recommendation of a specific strategy to protect our system.



# AutoStore | Fire Test Summary

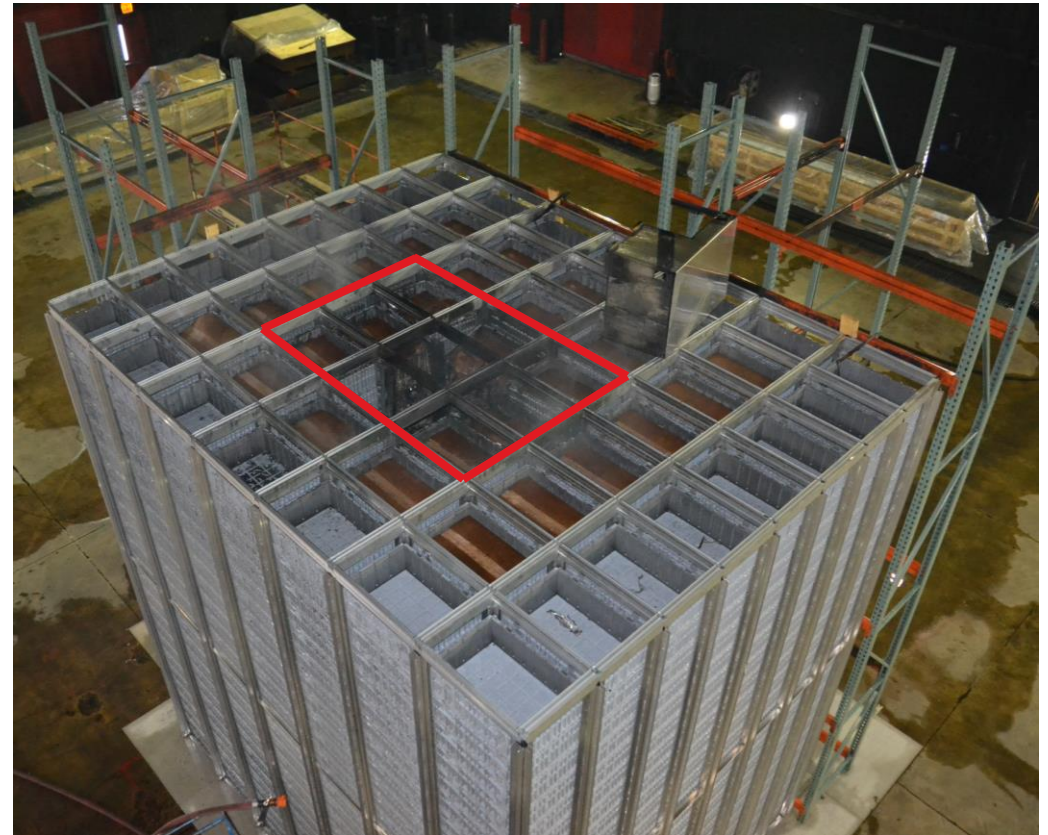
DATE	REPORT	DESCRIPTION	DATE	REPORT	DESCRIPTION
Aug. 2009	RISE Research Institute <u>Report:</u> RISE: P903499/Rev.1	Small-scale test - comparing fire characteristics of the primary two plastic compounds, HDPE and PP-ESD, used in AutoStore Bins	Feb. 2016	RISE Research Institute <u>Report:</u> RISE: 5P09926	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

## 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

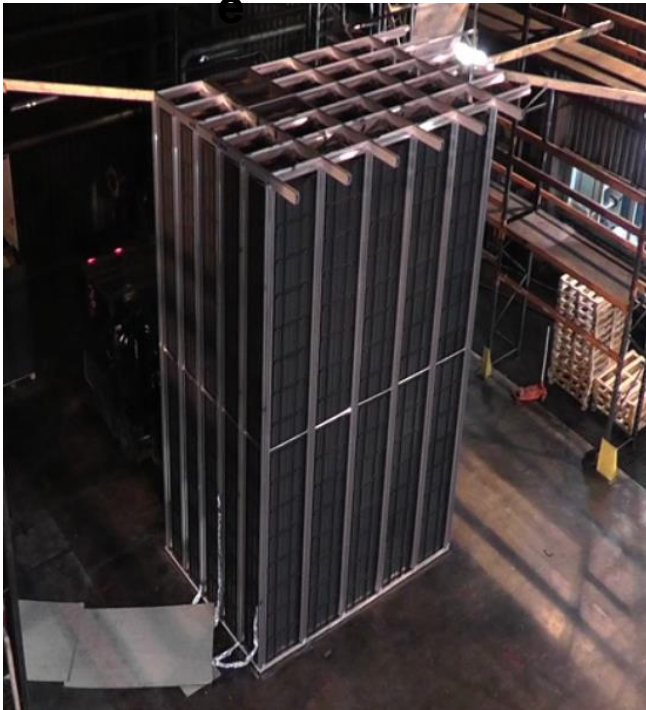


UL - Final Report - Project 4787818459 - ESFR Test - March 20\_2017

# Fire Safety | Comparison Pallet vs AutoStore (2013)

How you store your inventory has an impact on the fire development.

**AutoStor**



Same Bin

Different Storage  
method

Ignition Floor level

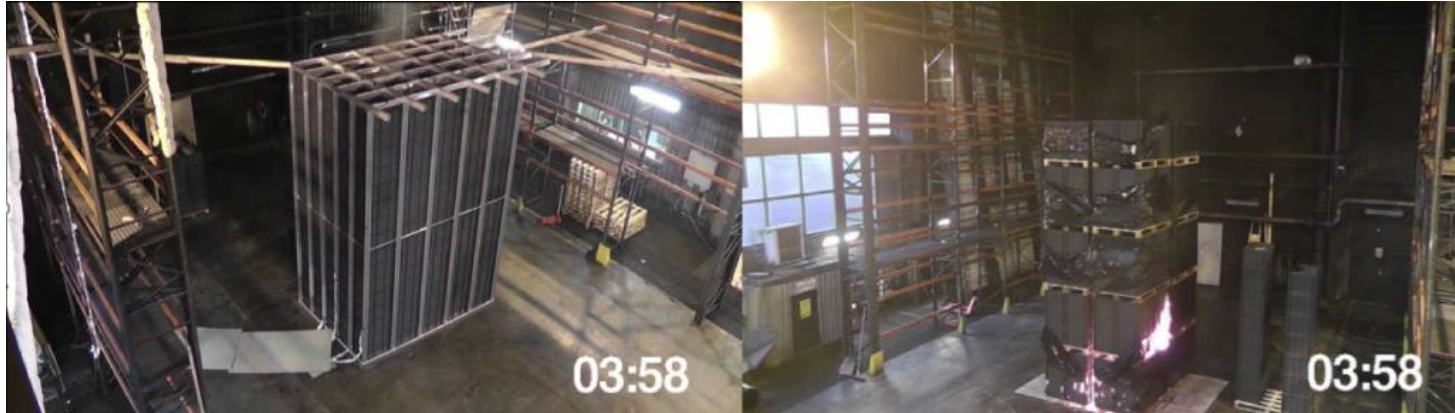
Standard Test  
Commodity

**Pallet Storage**

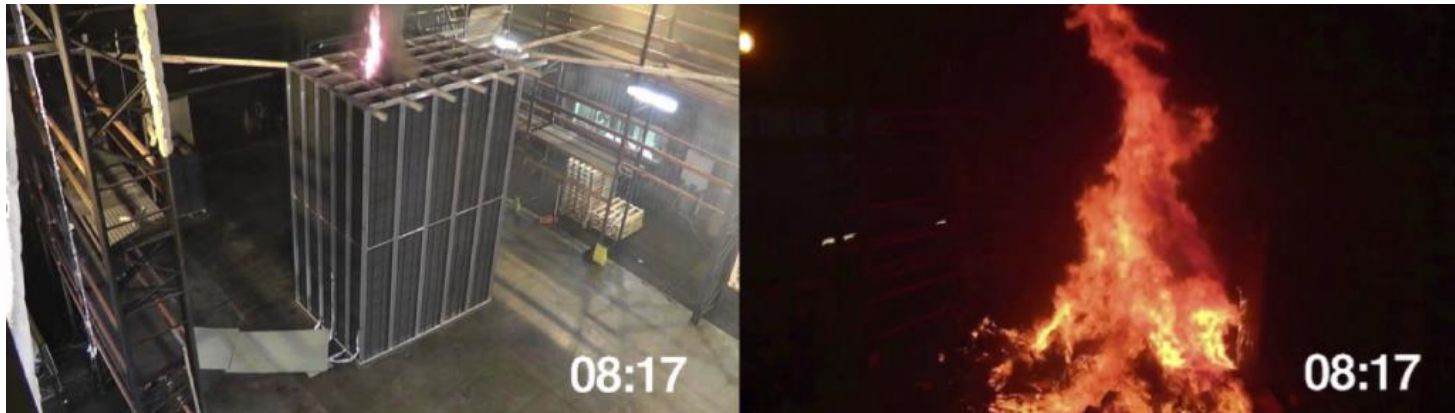


# Fire Safety | Compare AutoStore and pallets

**4 min:** Visible flames on the outside of the pallets, on the side. Only smoke from the AutoStore unit

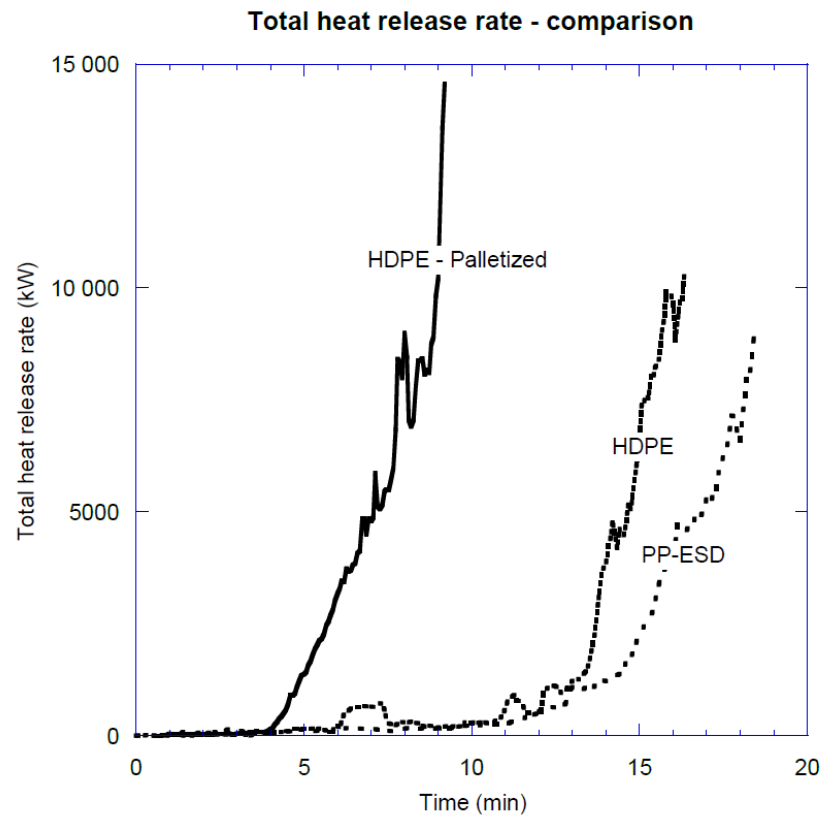


**8 min:** Visible flames above the AutoStore unit, the pallets storage has collapsed



# Fire Safety | Compare AutoStore and pallets

## Heat Release Rate



## Conclusion

How the storage array is constructed has an impact on the fire development

The initial fire growth rate is significantly faster for the bins in pallet storage compared to the AutoStore system

# UL test 2022 Final Extinguishment

## Acknowledgement:

These test were conducted at Underwriters Laboratories in Chicago with the support of FM Global

# AutoStore | UL 2022 – Test Goal

**GOAL:** Final Extinguishment Ceiling-Level Sprinklers only

## Criteria:

- 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

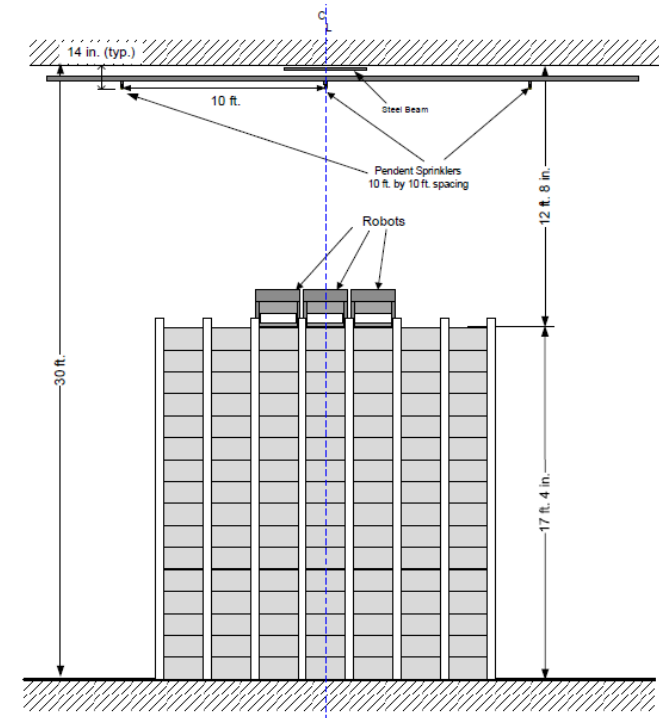
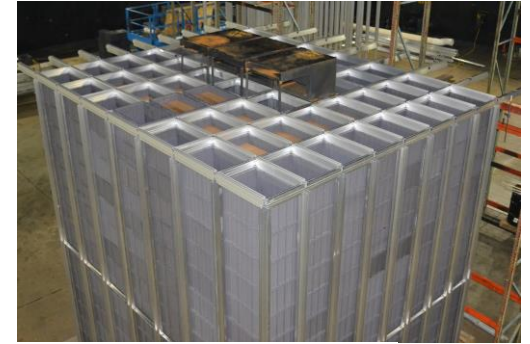


Figure 19 Elevation View of Test Arrangement from the East - Test 2 (Between Two Sprinklers on Separate Branchlines)



# 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 <sup>0.5</sup> (gpm/psig <sup>0.5</sup> )]	360 (25.2)			
Discharge Density [mm/m <sup>2</sup> (gpm/ft. <sup>2</sup> )	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

**Discharge duration:** 2 h

**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

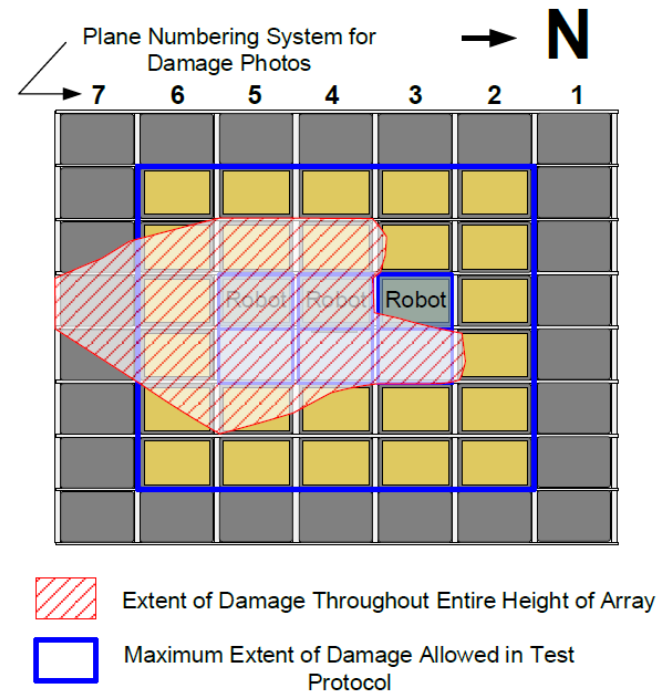
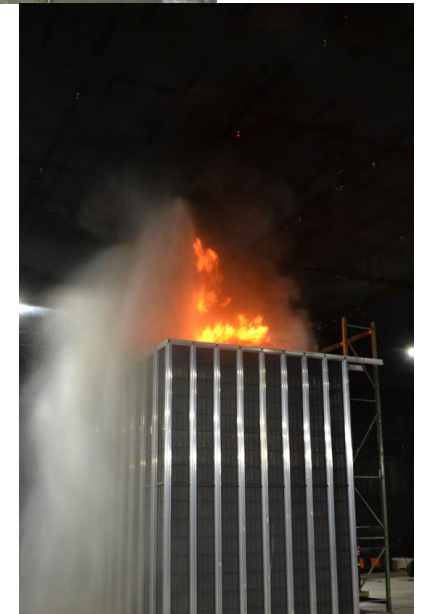


Figure 27 Overall Damage Assessment - Test 1 – Between Four Sprinklers



# AutoStore | UL 2022 – Results Test 2

**Ignition Location:** Between 2 sprinklers

**Duration test:** 1 h 5 min

**Discharge duration:** 1 h

**Number of sprinklers:** 1

**1. Sprinkler Operate:** 4 min 18 sec

**Final Extinguishment Yes/No:** Yes

**Manual efforts needed Yes/No:** No

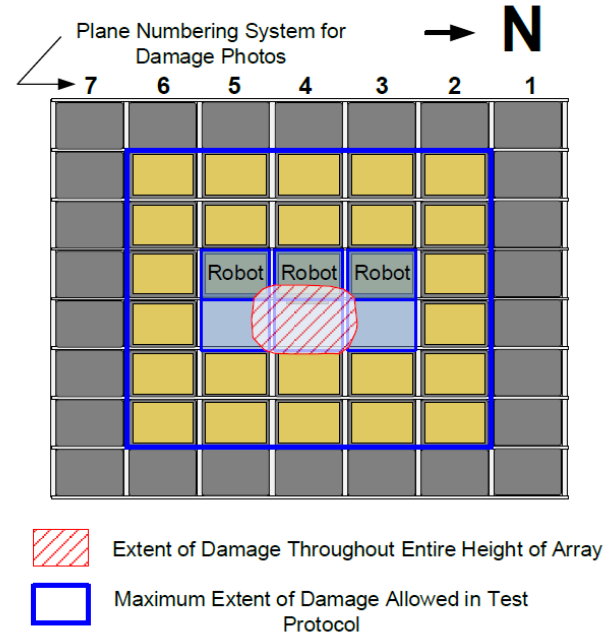


Figure 28 Overall Damage Assessment - Test 2 – Between Two Sprinklers



# AutoStore | UL 2022 – Results Test 3

**Ignition Location:** Between 4 sprinklers

**Duration test:** 2 h 6 min

**Discharge duration:** 2 h

**Number of sprinklers:** 3

**1. Sprinkler Operate:** 5 min 44 sec

**Final Extinguishment Yes/No:** Yes

**Manual efforts needed Yes/No:** No

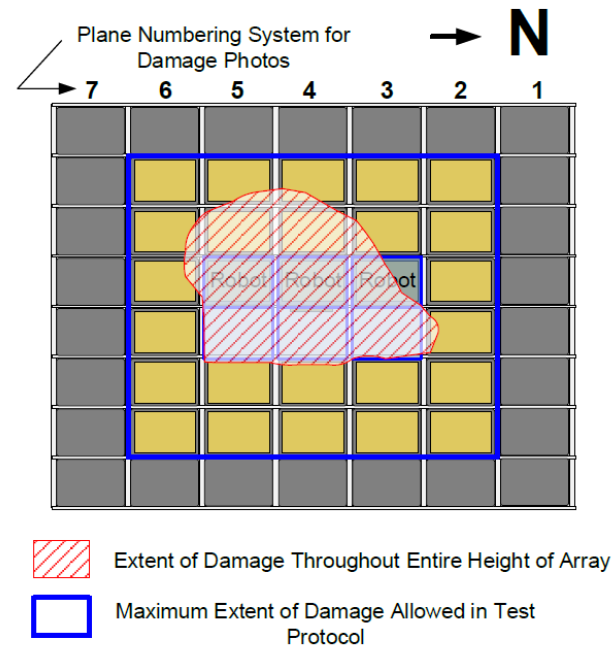
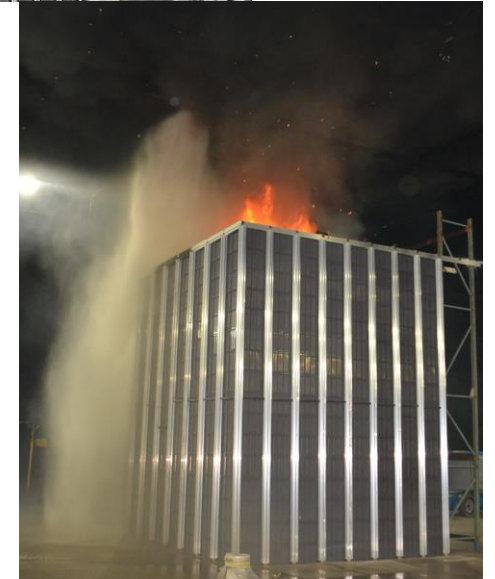


Figure 29 Overall Damage Assessment - Test 3 – Between Four Sprinklers



# AutoStore | UL 2022 – Results

## Test 4

**Ignition Location:** Under 1 sprinkler

**Duration test:** 1 h 5 min

**Discharge duration:** 1 h

**Number of sprinklers:** 1

**1. Sprinkler Operate:** 4 min 28 sec

**Final Extinguishment Yes/No:** Yes

**Manual efforts needed Yes/No:** No

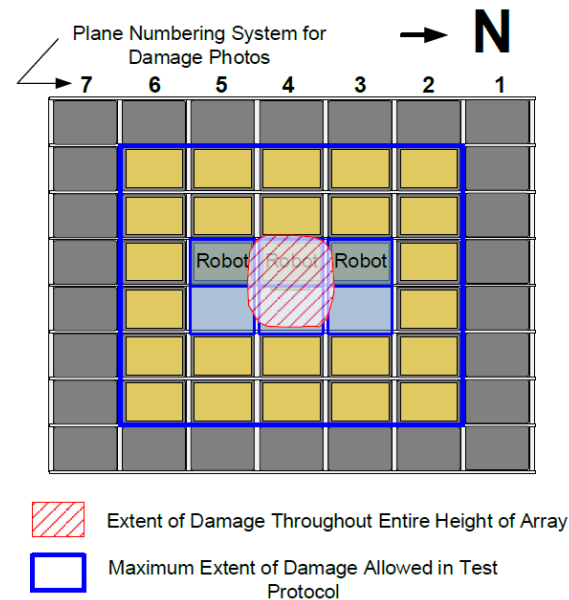


Figure 30 Overall Damage Assessment - Test 4 – Under One Sprinkler



# 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.

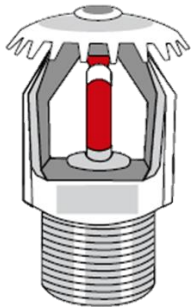
**Design Included in the FM Global DS 8-34 – Table 44 Alternative Ceiling Level sprinkler design for Final Extinguishment (Interim revision July 23)**



# AutoStore | What have we learned?

There are several fire protection options valid for an AutoStore System, among others

- Automatic Sprinklers
- Oxygen Reduction
- Foam

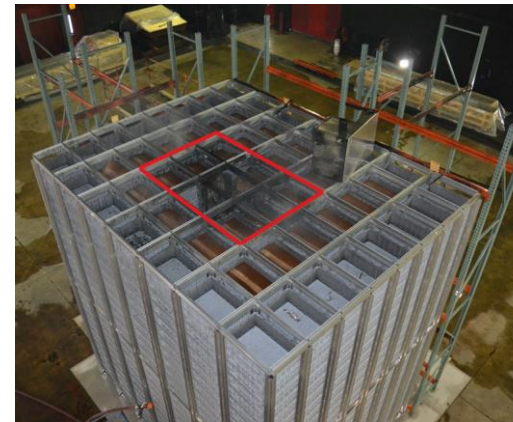


Rapid Vertical Growth  
=  
Rapid Sprinkler Operation and  
Suppression



Damage mainly limited to a 3 x 3  
cell area

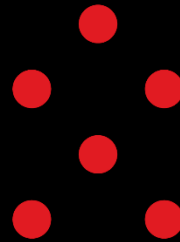
Limited number of sprinklers  
operate



## Final Extinguishment

- Manually – Method developed
- Can be achieved by ceiling level sprinklers only  
See specific design criteria in FM Global DS 8-34





Thank you for your attention!

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