TECHNICAL REPORT FOR CEN TC191/WG5/TG2

(In support of a Revision of EN 12845)

Incidental Storage of Plastics in Non-Storage Areas

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August 2020

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For

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1. Introduction

This document was prepared for the European Committee of Standardization, CEN TC191/WG5 to provide technical information for the full revision of EN12845 – Fixed firefighting systems - Automatic sprinkler systems - Design, installation and maintenance.

The experts of the committee noticed the recent change in the FM Global Data Sheet 3-26: The incidental storage or in-process storage for production areas is limited for goods without plastics up to 20 m² (220 ft^2), 3 m (10 ft) high and for goods with plastics up to 6 m² (64 ft^2), 1.8 m (6 ft) high, with a minimum 2.4 m (8 ft) aisle between multiple storage areas. A proposal was made to adopt these limitations in the current revision of EN12845, and with it to introduce incidental storage protection based on the values of Table 3 per FM Global Property Loss Prevention Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*.

The current published EN12845 (May 2020 – EN12845:2015 + A1:2019) allows a protection criterion of 5 mm/min (0.12 gpm/ft^2) over 216 m² (2330 ft^2)-wet and 270 m² (2900 ft^2)-dry in process storage of 50 m² (540 ft^2) over various heights. The EN 12845 differentiates various categories and storage configurations. Category (CAT) 1 is more or less equivalent to FM Class 1 to 2, CAT 2 is equivalent to FM Class 3/4; and CAT 3/4 would be equivalent to FM-Plastics cartoned and uncartoned, as the Material Factor 3, describes goods with a plastic content of >25 % (expanded) and >15 % (unexpanded) – (see Section 6.2.3 and Annex B of current EN12845). So currently:

CAT 1 in solid pile is 50 m² (540 ft^2) of 4 m (13.1 ft) [racks 3.5 m (11.5 ft)] high

CAT 2 in solid pile is 50 m² (540 ft^2) of 3 m (9.8 ft) [racks 3.5 m (11.5 ft)] high

CAT 3 in solid pile is 50 m² (540 ft^2) of 2.1 m (6.9 ft) [racks 1.7 m (5.6 ft)] high and

CAT 4 (>40 % expanded plastic) in solid pile or racks are 50 m² (540 ft^2) of 1.2 m (3.9 ft) high.

Per the current published EN12845, all these configurations can currently be protected with 5 mm/min (0.12 gpm/ft^2) water density. However, this report describes fire tests where all 49 sprinklers, representing 455 m^2 (4900 ft^2), operated even with a 12 mm/min (0.3 gpm/ft^2) density. A water density of 12 mm/min (0.3 gpm/ft^2) would be equivalent to a production of HHP 3 – High Hazardous Process Class 3. The highest density based on EN12845 for ordinary hazard OH 4 is 5 mm/min (0.12 gpm/ft^2) over 360 m² (3900 ft^2) wet and 7.5 mm/min (0.18 gpm/ft^2) over 325 m² (3500 ft^2) dry.

This information is provided to support the proposal of limiting the in-process or incidental storage to 6 m² (64 ft^2) [4 pallets] for goods with plastic content up to 1.8 m (6 ft) high and goods without plastics to 20 m² (220 ft^2) up to 3 m (10 ft) high with a minimum 2.4 m (8 ft) aisle between multiple storage areas. There is a high likelihood that larger footprints of storage in a worst-case scenario will overtax automatic sprinkler systems, i.e., too many sprinklers will open and the fire spread might not be controlled. The fire test results described in this report show that a sprinkler discharge density of 12 mm/min (0.3 gpm/ft^2) was sufficient to prevent fire spread to targets across a 2.4 m (8 ft) aisle.

2. FM Global Test Facilities Information

FM Global's 650-hectare (1,600-acre) Research Campus (RC) in West Glocester, Rhode Island is the premier site for property loss prevention, scientific research, and product testing. In 1967, the world's largest indoor fire testing facility began operation. The Factory Mutual Test Center, as it was then known, was the hub of countless fire, explosion and related tests for over 35 years. The tests ranged from simple to complex and from small to massive. The body of fire protection knowledge expanded greatly during this time.

In September 2003, a new, larger test facility was dedicated on the site. The new facility (See Figure 2-1) called the Fire Technology Laboratory (FTL) covers 10,000 m^2 (108,000 ft^2); the largest facility of its kind in the world. The FM Global FTL includes a wide variety of lab spaces used by both FM Global and FM Approvals to increase the testing capabilities and address even more challenging problems. Inside the FTL are multiple testing laboratories including the 3,120 m^2 (33,600 ft^2) Large Burn Laboratory (LBL).

Figure 2-1: Aerial View of the FM Global Research Campus.

The LBL consists of two movable ceilings (North and South Ceilings) and a 20-Megawatt (MW) Calorimeter located between both ceilings as shown in Figure 2-2. Both movable ceilings are 24.4 m (80 ft) long by 24.4 m (80 ft) wide and have the capability of ranging from 3.0 m (10 ft) to 18.3 m (60 ft) in height. The calorimeter has a diameter of 10.7 m (35 ft) with the inlet located at a height of 11.3 m (37 ft).

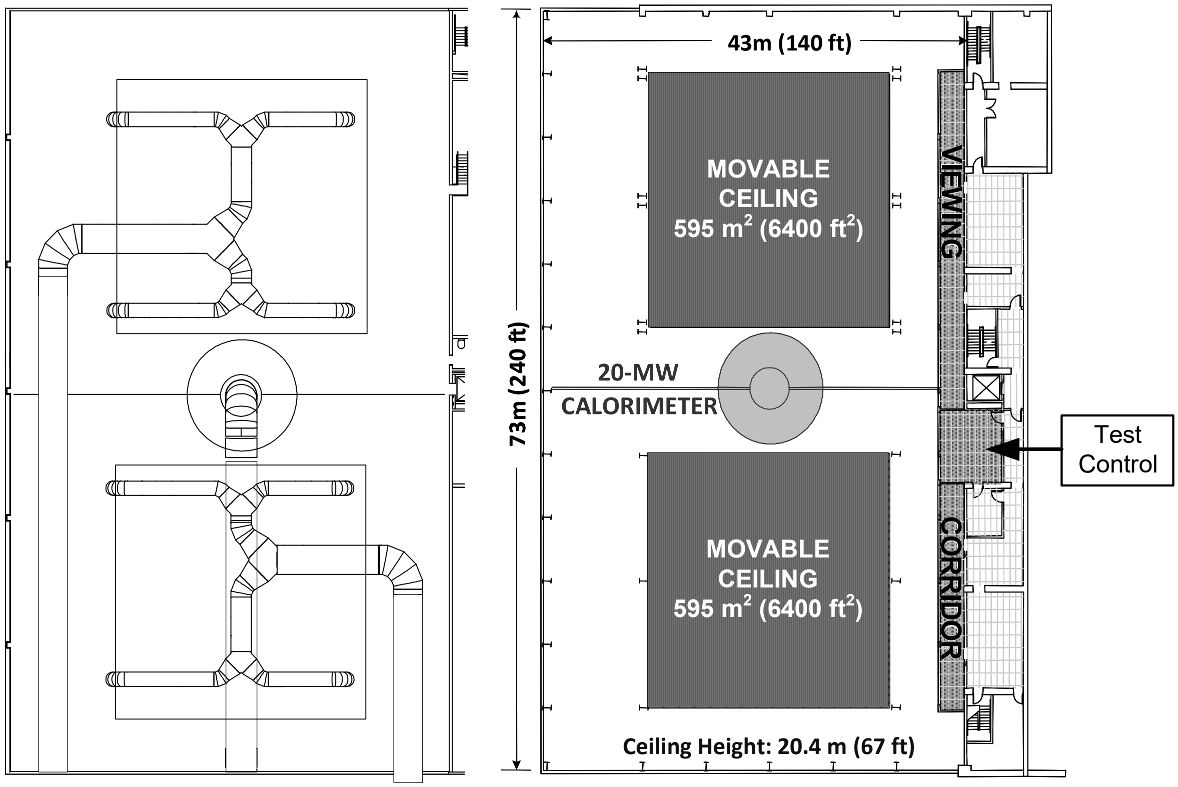


Figure 2-2: Layout of Large Burn Laboratory (Three Test Sites).

FM Global has taken careful measures to protect the environment throughout the facility and minimize the environmental impact of its operations. Air quality at the Fire Technology Laboratory is maintained by a highly efficient emissions control system. An air emission control system (AECS) is provided for the entire laboratory with an independent controller for each test location. Numerous instruments are installed to measure combustion gas concentrations, gas velocities and temperatures. The exhaust ducts connect to a wet electrostatic precipitator (WESP) prior to venting the scrubbed gas to the atmosphere. The WESP efficiently removes fine particulate matter such as dust and smoke from the airstream and has the capability to process more than 113 m^3/s (240,000 cfm) from the LBL. The concrete floor in the LBL is smooth and flat with drainage trenches surrounding each of the three test areas within the LBL. The water runoff from the suppression system is collected in the drains and sent to a water treatment system. The closed loop water treatment system is designed to handle about 760 L/min (200 gal/min). The water in the system is analyzed regularly to ensure its quality for testing. The water used for testing purposes, referred to as “Blue Water”, is stored in a tank with a capacity of 1,100,000 L (300,000 gal).

3. Incidental Plastics Storage Fire Tests

3.1 Test Conditions

Test conditions are summarized in Table 3-1. Tests 1, 2, and 3 represent incidental storage with limited (discrete) fuels. These tests used plastic pallets as a representative of uncartoned unexpanded plastic (UUP) in the main array and FM Global standard cartoned unexpanded plastic (CUP) commodity in the target array. The main and target arrays remained the same among Tests 1 - 3. The ceiling height was changed to represent different building designs. The sprinkler protection was the same for these tests except for the sprinkler response time index (RTI) and their manufacturers. The sprinklers were arranged in a 3-m × 3-m (10-ft × 10-ft) spacing with an operating pressure of 0.5 bar (7 psi). These tests evaluated the hazard posed by incidental storage using protection required in FM Global Property Loss Prevention Data Sheet 3-26 for an HC-3 occupancy. The goal of these tests was to determine the demand area of sprinklers and evaluate the potential damage to surroundings and structures with the change of sprinkler RTIs and ceiling heights from incidental storage.

Table 3-1: Conditions for Tests 1, 2, and 3 using plastic pallets in the main array and FM Global standard CUP commodity in the target array.

Test No.	1	2	3
Test setup			
Main Array Configuration	2x2, 13-pallet high		
Target Array Configuration	1x2, 3-carton high (CUP)		
Main Storage Height [m (ft)]	1.8 (6)		
Target Storage Height [m (ft)]	1.7 (5.6)		
Aisle Width [m (ft)]	2.4 (8)		
Flue Space (longitudinal, transversal) [m (ft)]	0 (0), 0 (0)		
Ignition Location	Offset, Under 1 sprinkler		
Ceiling Height [m (ft)]	9.1 (30)	9.1 (30)	18.3 (60)
Average Target Moisture Content [%dry (wet)]	6 (5.7)	6 (5.7)	7.3 (6.8)
Protection			
K-factor [L/min/bar$^{1/2}$ (gpm/psi$^{1/2}$)]	160 (11.2)		
Sprinkler Temperature Rating [°C (°F)]	68 (155)		
Spacing [m × m (ft × ft)]	3 × 3 (10 × 10)		
Discharge Pressure [bar (psi)]	0.5 (7)		
Design Density [mm/min (gpm/ft^2)]	12 (0.3)		

3.2 Test Setup

Figure 3-1 shows the schematics for Tests 1, 2, and 3. The main array consisted of four stacks of plastic pallets about 1.8 m (6 ft) tall. Each stack had 13 plastic pallets that were butted in both directions. The main array was centered beneath the ceiling under one sprinkler. Eight pallet loads of CUP commodity were placed on all four sides across a 2.4-m (8-ft) aisle as targets. Each target had three levels of CUP cartons and was about 1.7 m (5.6 ft) high. Two adjacent pallet loads were butted together. The ignition was located 0.6 m (2 ft) on the east side of the center of the main array (ignition was under a pallet). One standard full igniter was used for ignition.

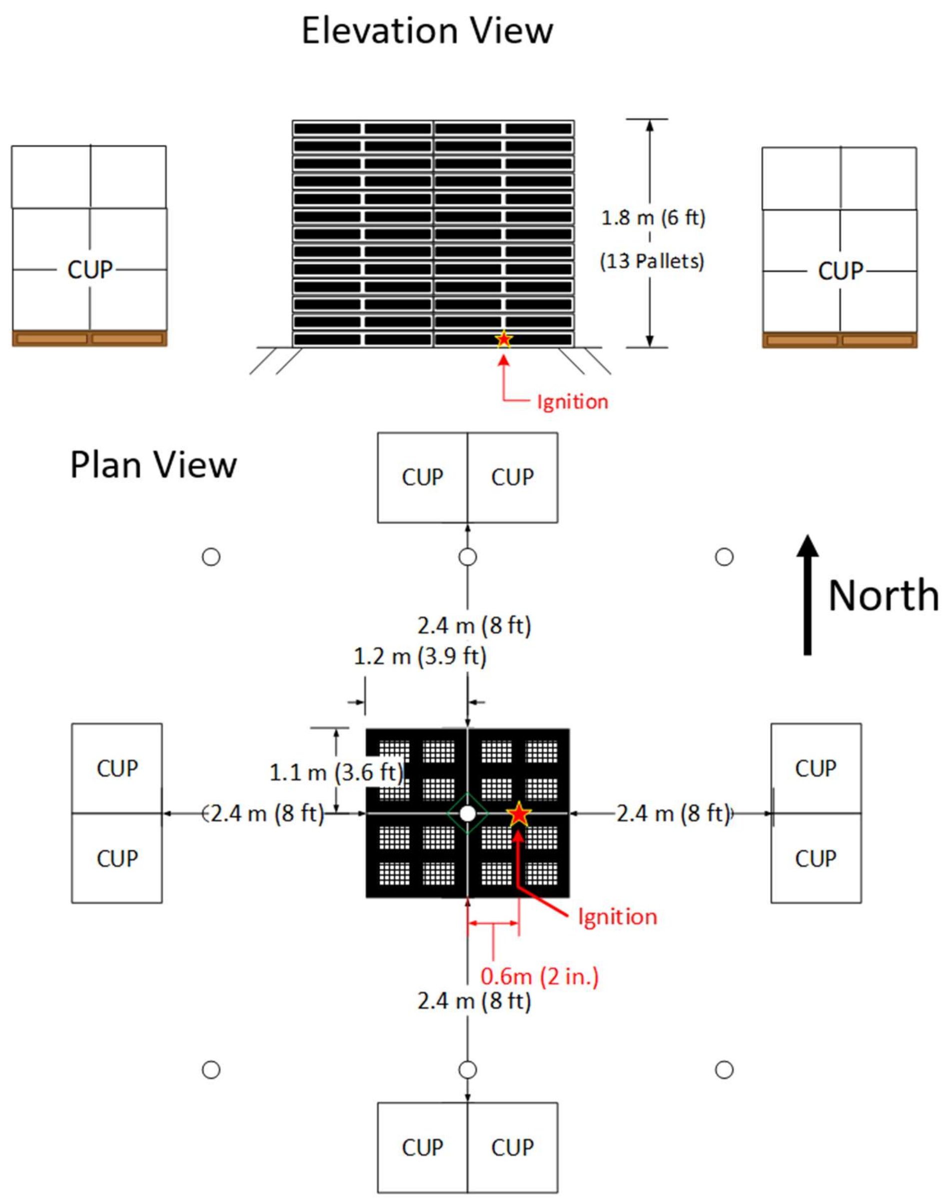


Figure 3-1: Schematics for Tests 1, 2, and 3: front elevation view shown on the top and plan view shown on the bottom. Sprinkler locations are marked by empty circles.

3.3 Sprinklers

Each test used 49 sprinklers installed on the ceiling with a 3 m by 3 m (10 ft by 10 ft) spacing. Test 1 used FM Approved upright sprinklers with a K-Factor of 160 L/min/bar$^{1/2}$ (11.2 gpm/psi$^{1/2}$), with a temperature rating of 68 °C (155 °F) and a nominal RTI of 36 m$^{1/2}$ s$^{1/2}$ (65 ft$^{1/2}$ s$^{1/2}$).

Tests 2 and 3 used FM Approved upright sprinklers with a K-Factor of 160 L/min/bar$^{1/2}$ (11.2 gpm/psi$^{1/2}$), a temperature rating of 68 °C (155 °F) and a nominal response time index (RTI) of 135 m$^{1/2}$ s$^{1/2}$ (245 ft$^{1/2}$ s$^{1/2}$).

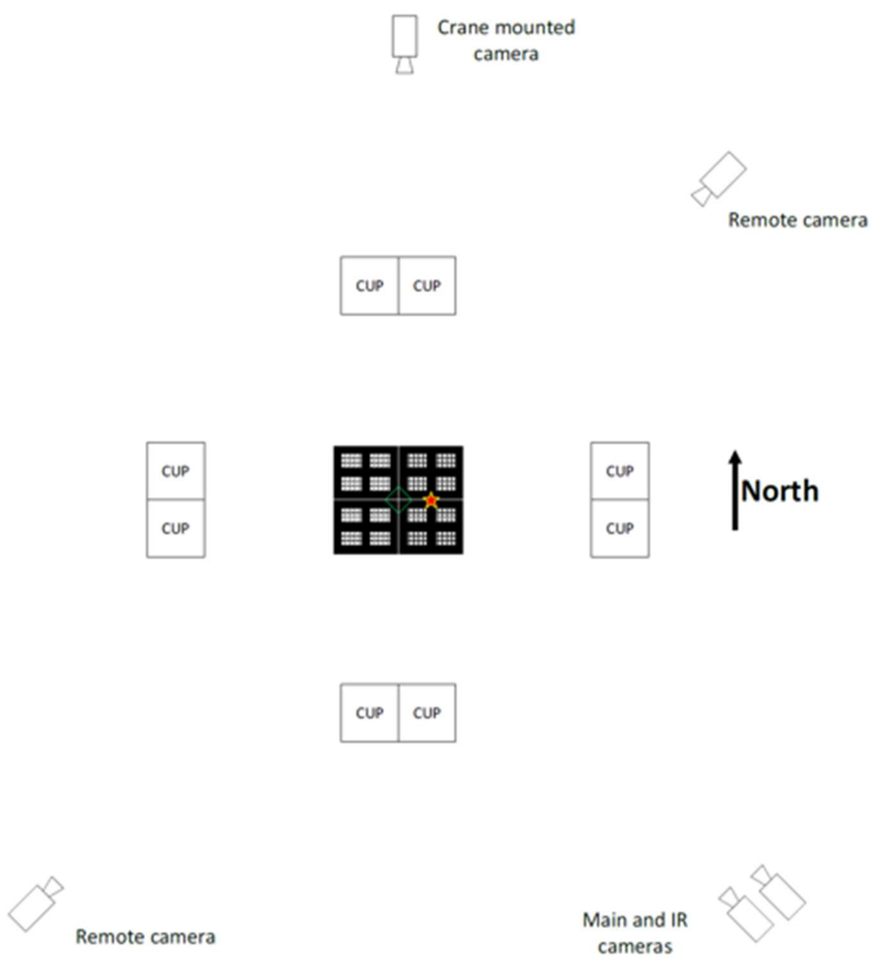


Figure 3-2: Camera layout for Tests 1, 2, and 3.

3.4 Instrumentation and Documentation

Instrumentation was used to monitor both environmental and test conditions. Environmental conditions included relative humidity and dry-bulb temperature of the air inside the lab prior to each test. Test conditions were measured using thermocouples installed on the ceiling and gas analyzers and flow meters in the exhaust duct. Thermocouples had a nominal RTI of 8 m$^{1/2}$ s$^{1/2}$ (14.5 ft$^{1/2}$ s$^{1/2}$) and were used for ceiling gas temperatures. Thermocouples were also embedded in a cross-shaped 6.35 mm (0.25 in.) thick steel angle made from two 0.6 m (2 ft) long pieces. The exhaust duct collected combustion gases above the ceiling. The data recorded in the exhaust duct were time resolved but with an unquantified delay due to the presence of the ceiling and the plenum above it. The sprinkler system was controlled and monitored using pressure controllers and flow meters.

Documentation for each test included digital and analog data acquisitions, videos, still photography, and audio recordings of the observation made during the test. The data acquisition system collected data from all instruments described above. The video documentation as shown in Figure 3-2 included three high-definition digital video cameras and an infrared (IR) camera (Bullard® T4MAX) for qualitative assessment of the fire. One crane-mounted camera was placed on the north side to provide a top view of the fire.

Table 3-2: Summary of the results for Tests 1, 2, and 3.

Test No.	1	2	3
Length of Test [min: s]	13:00	13:00	13:00
First Sprinkler Operation [s]	235	243	370
Last Sprinkler Operation [s]	632	637	723
Total Sprinkler Operation	49	49	49
Peak 1-sec Averaged Steel Temperature [°C (°F)] @ Time [s]	494 (921) @794	486 (906) @ 971	64 (147) @ 785
Convective Heat Release Rate at sprinkler operation (kW)	480	700	3180
Convective Fire Growth Rate Before Water Application (kW/s)	7	10	26
Total Energy Release (MJ)	5660	5380	9200
Time of Target Involvement [min: s]	No Target Involvement	No Target Involvement	No Target Involvement

3.5 Test Results

Table 3-2 summarizes critical results for Tests 1, 2, and 3. All tests were terminated 13 minutes after ignition once all the sprinklers operated. No target was involved by the end of the test. Tests 1 and 2 opened the first and the last sprinklers at 240 s (4 min) and 635 s (10 min 35 s), respectively, which are earlier than the corresponding times in Test 3. Tests 1 and 2 also showed comparable ceiling gas and steel temperatures, which are much higher than those in Test 3. These differences are the result of the increased ceiling height in Test 3. The higher ceiling delayed the sprinkler activation due to enhanced cooling via entrainment of ambient air into the fire plume. The convective heat release rate (CHRR) was estimated based on the storage height and gas temperatures underneath the ceiling using fire plume and ceiling layer correlations. The CHRR before sprinkler activation for Test 1 was slightly lower than that for Test 2, which was due to the lower sprinkler RTI in Test 1. The CHRR for Test 3 before sprinkler activation was much larger than those for Tests 1 and 2 because of a significantly delayed sprinkler activation with an increased ceiling height. The convective fire growth rate (CFGR) was calculated as the slope of CHRR. The CFGR for Test 1 before sprinkler activation was slightly lower than that for Test 2 and significantly lower than that for Test 3. The relative trends of CFGR among the three tests are consistent with those of CHRR. The total energy release was obtained by integrating the chemical heat release rate measured in the exhaust duct. Test 3 consumed almost two times the fuel compared to Tests 1 and 2.

Figures 3-3 to 3-5 show photographs of Tests 1 to 3 at different times after ignition. For Test 1 at 30 s, white smoke was observed above the top of the main array. The fire started to grow vertically. At 235 s (3 min 55 s), the fire was about 3.7 m (12 ft) high and activated the first sprinkler. The water application did not control the fire, resulting in activation of more sprinklers. At 360 s (6 min), the fire came out of the south side and formed a small pool fire on the floor. The pool fire was later suppressed when additional sprinklers operated. At the end of the test, the fire reached the ceiling. The fire history for Test 2 was similar to that of Test 1. The minor differences resulted from the difference in RTI of sprinklers. In contrast, Test 3 showed a significantly different fire development process. Due to the delay in sprinkler activation, the fire came out on both south side and east side when the first sprinkler operated at 370 s (6 min 10 s). The fire size was much larger than that in Tests 1 and 2. Larger pool fires were formed at 463 s (7 min 43 s). Those pool fires were also suppressed before the end of the test with the operation of more sprinklers. All tests were terminated via fire hose stream and not due to the sprinkler operation.

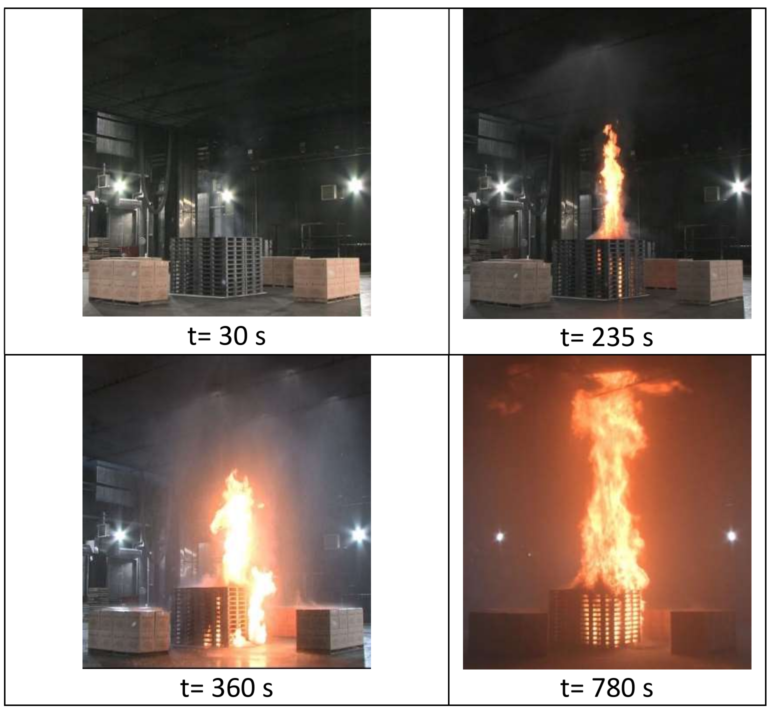


Figure 3-3: Photographs of Test 1 at different times after ignition.

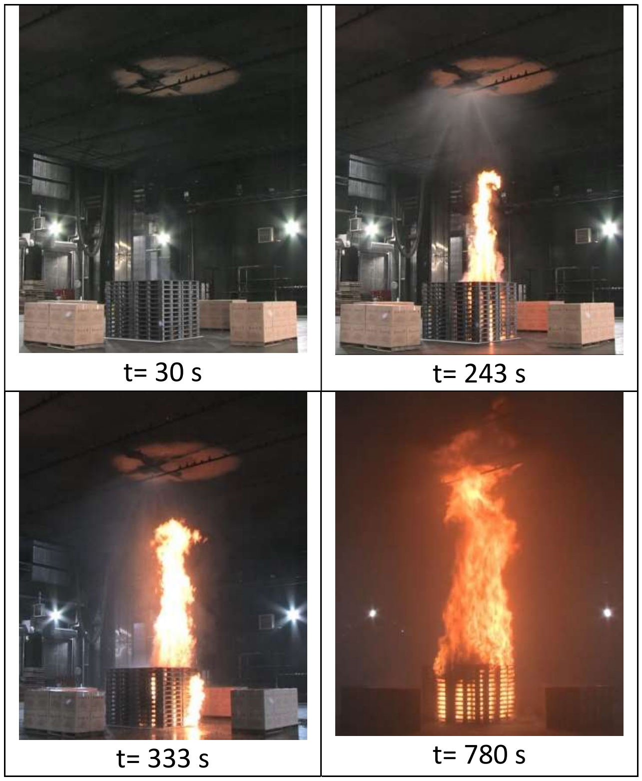


Figure 3-4: Photographs of Test 2 at different times after ignition.

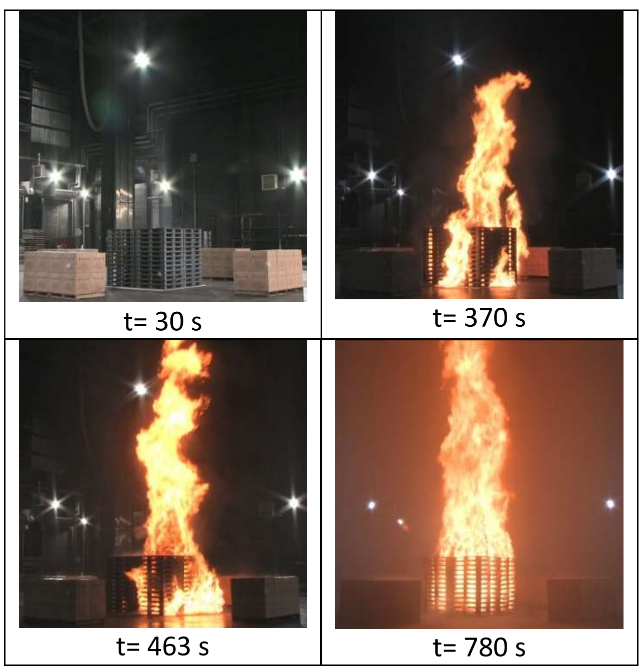
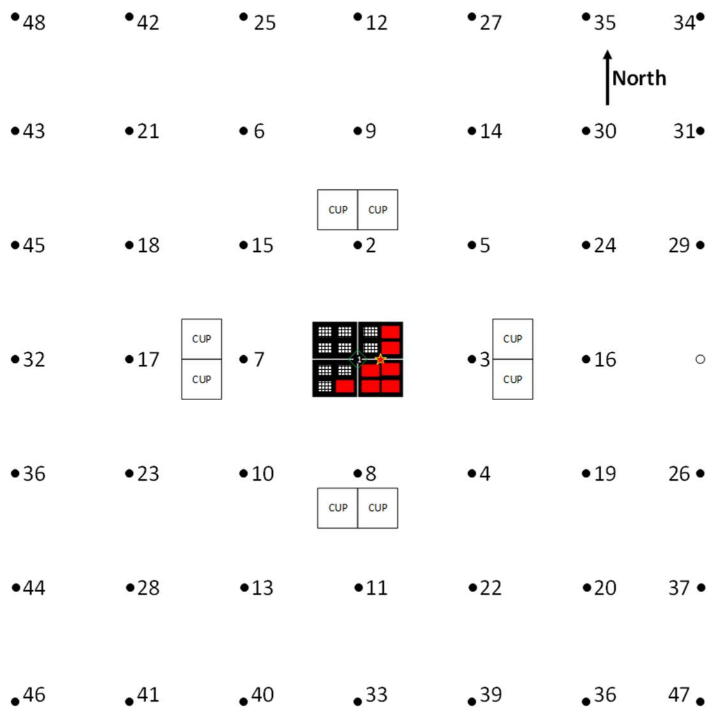
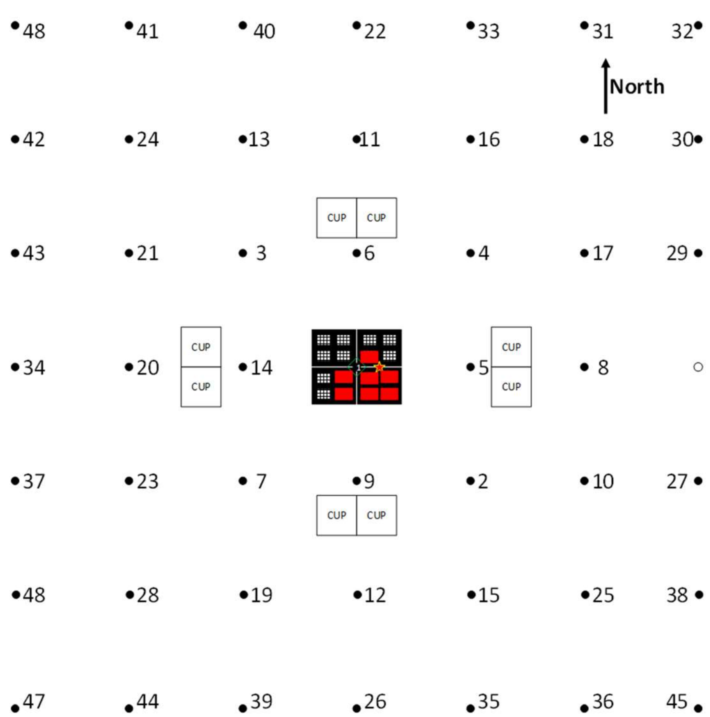


Figure 3-5: Photographs of Test 3 at different times after ignition.



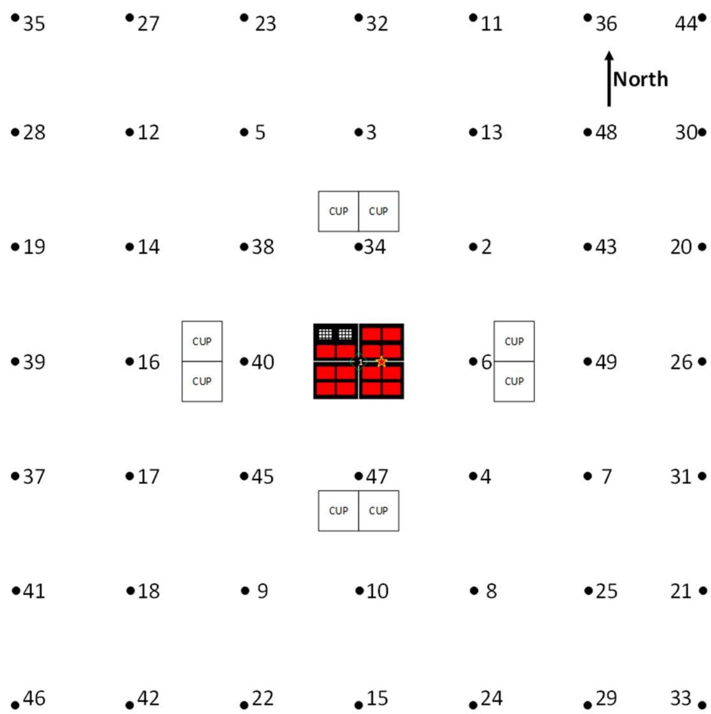
Order	Time (s)	Order	Time (s)
1	235	26	448
2	336	27	451
3	354	28	455
4	355	29	458
5	355	30	460
6	359	31	464
7	362	32	464
8	374	33	470
9	376	34	472
10	380	35	474
11	388	36	505
12	396	37	507
13	402	38	515
14	403	39	525
15	425	40	525
16	427	41	530
17	428	42	541
18	433	43	547
19	434	44	553
20	435	45	565
21	439	46	592
22	439	47	599
23	442	48	632
24	445		
25	446		

Figure 3-6: Sprinkler operation pattern and top view of damage assessment for Test 1. The number marks the order of sprinkler activations.



Order	Time (s)	Order	Time (s)
1	243	26	448
2	257	27	451
3	351	28	462
4	356	29	467
5	361	30	472
6	361	31	481
7	365	32	481
8	372	33	484
9	374	34	485
10	375	35	493
11	375	36	500
12	376	37	502
13	384	38	502
14	386	39	505
15	390	40	518
16	393	41	538
17	397	42	543
18	403	43	550
19	407	44	579
20	409	45	595
21	413	46	609
22	418	47	636
23	419	48	537
24	421		
25	425		

Figure 3-7: Sprinkler operation pattern and top view of damage assessment for Test 2. The number marks the order of sprinkler activations.



Order	Time (s)	Order	Time (s)
1	370	26	536
2	458	27	538
3	465	28	538
4	479	29	540
5	480	30	541
6	480	31	542
7	480	32	543
8	488	33	547
9	495	34	556
10	497	35	562
11	501	36	564
12	502	37	566
13	506	38	571
14	507	39	571
15	508	40	571
16	510	41	571
17	512	42	572
18	512	43	572
19	519	44	584
20	520	45	593
21	520	46	599
22	520	47	607
23	526	48	620
24	528	49	723
25	531		

Figure 3-8: Sprinkler operation pattern and top view of damage assessment for Test 3. The number marks the order of sprinkler actuations.

Figures 3-6 to 3-8 show the sprinkler operation pattern and activation times, as well as the top view of damage to the main array for Tests 1 to 3. Note that there was a malfunction in the trip wire for the sprinkler on the eastern edge of the array in both Tests 1 and 2. The fire was growing uncontrolled even with all 49 sprinklers operated. Ultimately all of the commodity would have been involved without fire fighter intervention. Most sprinklers were far away from the fire and did not discharge water to aid suppression. However, the operation of these sprinklers does show that a demand area larger than the movable ceiling (590 m^2 [6,400 ft^2]) needs to be considered to ensure that an adequate water supply is included in the protection recommendations. Before the hose stream were applied, the fire created significant damage to the main array. For Tests 1 and 2, the fire consumed most of the southeastern pallet and caused partial damage to the adjacent pallets. For Test 3, the fire consumed most of the main array. The consumption occurred to the thin mesh portion of the plastic pallets and charring was observed over the rest of the pallets.

3.6 Analysis and Summary

The results show that for relatively small quantities of uncartoned unexpanded plastic (UUP) storage (6 m^2 [64 ft^2]), a sprinkler discharge density of 12 mm/m^2 (0.3 gpm/ft^2) cannot be expected to suppress or control the fire.

With 49 sprinklers operating in each test, this represents a much larger demand area than for a typical non-storage sprinkler demand area of 230 m^2 (2500 ft^2).

However, the results show that with a sprinkler discharge density of 12 mm/min (0.3 gpm/ft^2) and separation between storage arrays of 2.4 m (8 ft), the fire did not spread to involve adjacent fuel.

These tests show that sprinkler protection typical for a non-storage occupancy is not capable of suppressing or controlling a fire involving small quantities of UUP but, with good separation and pre-wetting from sprinkler protection, the adjacent fuel is not expected to become involved.

The effectiveness of this approach is predicated on the minimum separation of 2.4 m (8 ft) being provided. When these conditions are maintained in a non-storage occupancy, and with sprinkler protection adequate for the surrounding occupancy, the storage may be considered incidental to the occupancy.

4. Conclusions

This report described how easily an automatic sprinkler system can be overtaxed with goods having plastic content and the importance of an aisle of 2.4 m (8 ft) between incidental storage in production areas. FM Global changed its guidelines and chose to limit incidental storage for up to FM Global Class 3 commodities to 20 m^2 (220 ft^2) and 6 m^2 (64 ft^2) for plastics based on the sprinkler design requirements for production areas. In addition, FM Global offers protection solutions for larger low-pile storage areas in Data Sheet 3-26, Table 3. Research demonstrates that for up to FM Global Class 3 commodities about 15 to 20 % of fires can operate all sprinklers in the design area. When plastics are involved, all sprinklers in the design area can operate with even smaller fire areas. Table 3 in Data Sheet 3-26 has been developed through full-scale fire testing to provide fully adequate protection solutions for unlimited area low-pile storage.

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