ROLL PAPER STORAGE

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1.0 SCOPE

This data sheet provides loss prevention guidelines for the protection of roll paper stored on the floor, on-end, on-side, and held horizontally by axial rods on supporting structures, in racks, and on pallets.

1.1 Hazard

Paper is easy to ignite. Rolls stored on-end burn rapidly when clear, unobstructed, vertical flues are available. Fire will spread vertically in flues and will burn through the outer layer exposing a new dry surface to burn. Paper will unwind from the rolls unless there is an arrangement, such as a standard array, to prevent exfoliation. As the rolls shed their outer layers that have been wet by sprinkler water, dry paper surfaces are exposed, providing a continuous hazard. In addition, fire may spread by contact or radiation to adjacent piles unless there are sufficient separation distances or adequate pre-wetting. Roll paper is also very susceptible to smoke and water damage.

Tissue paper (previously classified as lightweight paper and now classified as RP 1) is of particular concern. When tissue is stored in an open array, fire can spread rapidly through the storage array, opening many sprinklers as it spreads. Even when tissue is stored in a standard array, fire can spread rapidly along the face of the storage, operating many sprinklers as the flame spreads from flue to flue, driven by the exfoliation of the burning stacks. Due to the high absorptive properties of tissue, the sprinkler water does not have a chance to pre-wet adjacent rolls and therefore the fire has an easy path of dry paper to burn to the extent of the storage array. Furthermore, this paper has a much lower ignition energy than hard-surface papers (as described in Appendix A), allowing even smaller ignition sources to ignite the adjacent paper and allow rapid fire spread.

As the storage height of roll paper increases, the resultant hazard increases and requires larger sprinklers with greater flow and pressure to control these types of fires. These high storage fires can grow so rapidly that many sprinklers operate almost simultaneously. This simultaneous operation can overtax a sprinkler system if the water supply is not capable of maintaining system design pressure at the critical initial stages of the fire and throughout its duration.

1.2 Changes

January 2023. Interim revision. The following changes were made:

A. Removed allowance of dry-pipe systems for RP 1 protection in Section 2.2.3.

B. Updated manufacturing area RP 1 in-process storage guidance in Section 2.2.5.

C. Reorganized Section 2.2.6 and updated RP 1 on-floor storage protection guidance, including Table 2.2.6.1.2.

D. Expanded RP 1 belly wrapped protection options in Table 2.2.6.5.3.

E. Clarified hose demand and system duration recommendations for wrapped RP 1 in Section 2.2.6.8

F. Added pre-incident plan recommendations to human element in Section 2.4.

G. Added supporting material related to on-end storage of RP 1 in Section 3.1.2.1 and Section 3.3.

H. Added definition of semi-standard array to Appendix A.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 Construct storage facilities in accordance with the relevant FM property loss prevention data sheets. See the 1-series data sheets for guidelines relevant to the construction features of most storage facilities (e.g., Data Sheet 1-12, *Ceilings and Concealed Spaces)*.

2.1.2 Fire protection of building column and overhead steel is not necessary if all of the protection guidelines in this data sheet are met.

2.2 Protection

2.2.1 Roll Paper Classification

2.2.1.1 Classify roll paper per the following:

A. Absorbent paper is classified as RP 1. Absorbent paper is any paper that is not considered hard surface.

B. Hard-surface paper is classified as RP 2 or RP 3, depending on the percentage by weight of inert content and basis weight (lb/1000 ft^2 [g/m^2]). See Appendix A for definitions of inert content and paper classification types.

2.2.1.2 Determine the classification of hard-surface paper in accordance with Figure 2.2.1.2.1-1 (imperial) or Figure 2.2.1.2.1-2 (metric).

2.2.1.3 Special Paper Classifications

2.2.1.3.1 Classify asphalt-laminated paper as plastic-coated RP 3 paper. Asphalt-laminated paper is made up of two or more sheets of paper bonded together with one or more layers of asphalt.

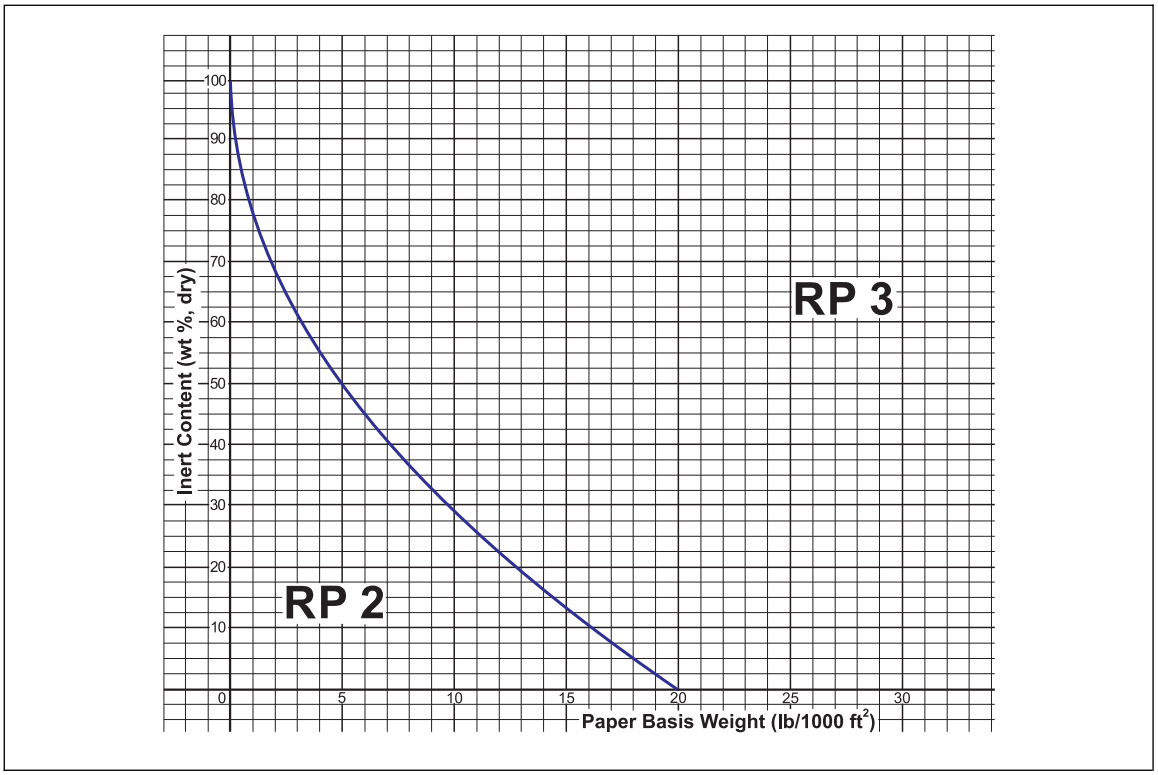

Fig. 2.2.1.2.1-1. Hard-surface roll paper classification (imperial)

2.2.1.3.2 Classify raw, paper-based roofing felt (without asphalt) as RP 3 paper. Roofing felt, in this case, is porous, soft paper made from cotton and wool rags and paper stock. Roofing felts with synthetic content should be treated as nonwovens in accordance with Data Sheet 8-23.

2.2.1.3.3 Classify solid-piled or palletized baled pulp as a Class 3 commodity and provide protection in accordance with Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.

2.2.1.3.4 Classify rolled pulp as RP 3.

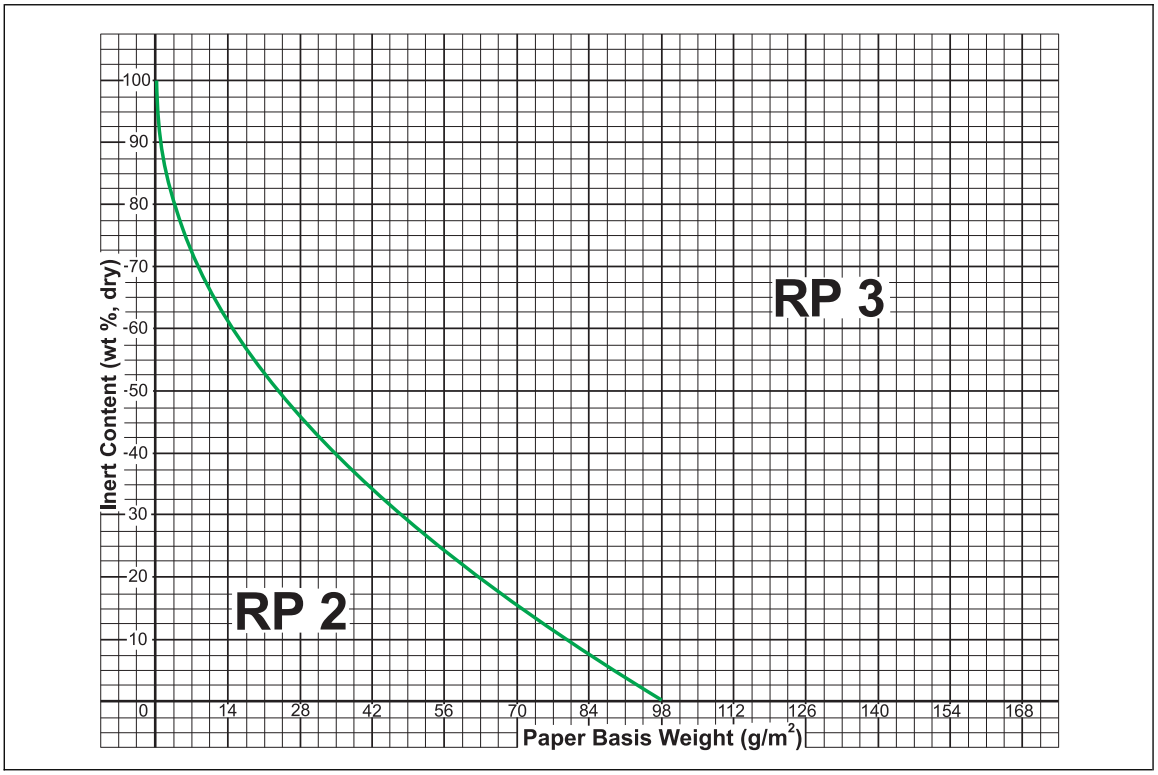

Fig. 2.2.1.2.1-2. Hard-surface roll paper classification (metric)

2.2.2 General Protection Guidelines

2.2.2.1 Use FM Approved storage sprinklers. The types, ratings, and sizes (e.g., Pendent, QR, K14.0) should be aligned with that recommended in the fire protection tables. Install automatic sprinkler systems in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, to ensure their compatibility with the facility's construction features such as sloped ceilings, heat and smoke vents, and draft curtains.

2.2.2.2 Use wet pipe sprinkler systems when possible for all types of roll paper storage.

2.2.2.3 Design for the maximum anticipated storage height considering the size of the rolls, limitations of mechanical handling equipment, and a minimum 3 ft (0.9 m) clearance between the top of the storage and ceiling sprinkler deflectors.

2.2.2.4 Protect locations having mixed storage or several different storage arrangements for the greatest storage hazard.

2.2.2.5 Protect palletized roll paper as an open array when the pallets are larger than the diameter of the roll (e.g., when there are flue spaces in all directions). When the roll diameter is larger than the pallet, evaluate based on how the rolls are configured. See Appendix A for definitions of standard and open array.

2.2.3 Dry Pipe and Preaction Systems

2.2.3.1 When wet systems are impractical, use dry-pipe or preaction systems to protect RP 2 or RP 3 paper in any storage array. Do not use dry-pipe systems to protect RP 1 paper in any storage array.

2.2.3.2 Use 286°F (141°C) temperature-rated, standard response, upright sprinklers for dry sprinkler systems; design the system to have a maximum 40-second water delivery time based on the operation of the most remote four sprinklers (2 sprinklers on 2 lines).

2.2.3.3 Do not use gridded dry-pipe and gridded pre-action systems. These systems result in delayed water delivery times.

2.2.4 Outdoor Storage of Roll Paper

2.2.4.1 Provide separation distances from buildings to outdoor (yard) storage of roll paper per DS 1-20. Use the light/ordinary category in DS 1-20 for on-side roll paper, and the storage category in DS 1-20 for on-end roll paper.

2.2.5 Roll Paper in Manufacturing Areas

2.2.5.1 For RP 1, where existing sprinkler protection for the manufacturing occupancy does not meet the recommendations in Section 2.2.6, limit the in-process storage area to 200 ft^2 (19 m^2), not to exceed 10 ft (3 m) high. Separate in-process storage areas from other combustible materials by a minimum of 8 ft (2.4 m) wide aisles.

2.2.5.2 For RP 2 and RP 3, where existing sprinkler protection for the manufacturing occupancy does not meet the recommendations in Section 2.2.6, limit the in-process storage to one of the following:

A. For stack heights up to 5 ft (1.5 m), limit the in-process storage area to 1000 ft^2 (93 m^2). Separate in-process storage areas from other combustible materials by a minimum of 8 ft (2.4 m) wide aisles.

B. For stack heights up to 10 ft (3 m), limit the in-process storage area to 200 ft^2 (20 m^2). Separate in-process storage areas from other combustible materials by a minimum of 8 ft (2.4 m) wide aisles.

C. For stack heights up to 15 ft (4.5 m), limit the footprint to a maximum of four stacks or 100 ft^2 (9.3 m^2), whichever is smaller. Separate in-process storage areas from other combustible materials by a minimum of 15 ft (4.5 m) wide aisles.

Although fire from the burning stacks may cause as many sprinklers to operate as a larger amount of burning paper, the fire spread will be limited unless other combustible materials are nearby.

2.2.6 Indoor Roll Paper Stored in a Dedicated Storage Area

2.2.6.1 Protection of RP 1 Paper Stored On-Floor

2.2.6.1.1 Protect all RP 1 using one of the following methods, listed in order of preference:

A. Wrap the paper on both the sides and ends (cocoon wrap) in accordance with Section 2.2.6.5.4 and provide protection in accordance with Section 2.2.6.3.

B. Wrap the paper on the sides only (belly wrap) in accordance with Section 2.2.6.5.4 and provide protection in accordance with Section 2.2.6.5.3.

C. Separate the storage area into zones and provide automatic sprinkler protection in accordance with Section 2.2.6.1.2.

D. Provide storage in a detached building with a minimum separation distance from other structures in accordance with Data Sheet 1-42, *Maximum Foreseeable Loss Limiting Factors*.

E. Install an MFL wall per Data Sheet 1-42 between the parent roll storage and manufacturing area.

2.2.6.1.2 Protect RP 1 paper stacked on-side or on-end in a semi-standard or standard array per the following:

A. Limit storage to a maximum height of 27 ft (8.2 m).

B. Limit the ceiling height to no greater than 40 ft (12.2 m).

C. Install a wet-pipe sprinkler system in accordance with Table 2.2.6.1.2.

D. Separate the storage area into zones that meet the following criteria:

1. Provide separation between storage zones with either:

a. Floor to ceiling noncombustible walls, or

b. Draft curtains with a minimum depth of 4 ft (1.2 m) and a maximum depth of 5 ft (1.5. m), centered between the adjacent rows of ceiling sprinklers, and centered over a minimum 8 ft (2.4 m) wide aisle. See Figure 2.2.6.1.2.

2. Determine the ceiling sprinkler demand area and maximum allowable zone size as follows:

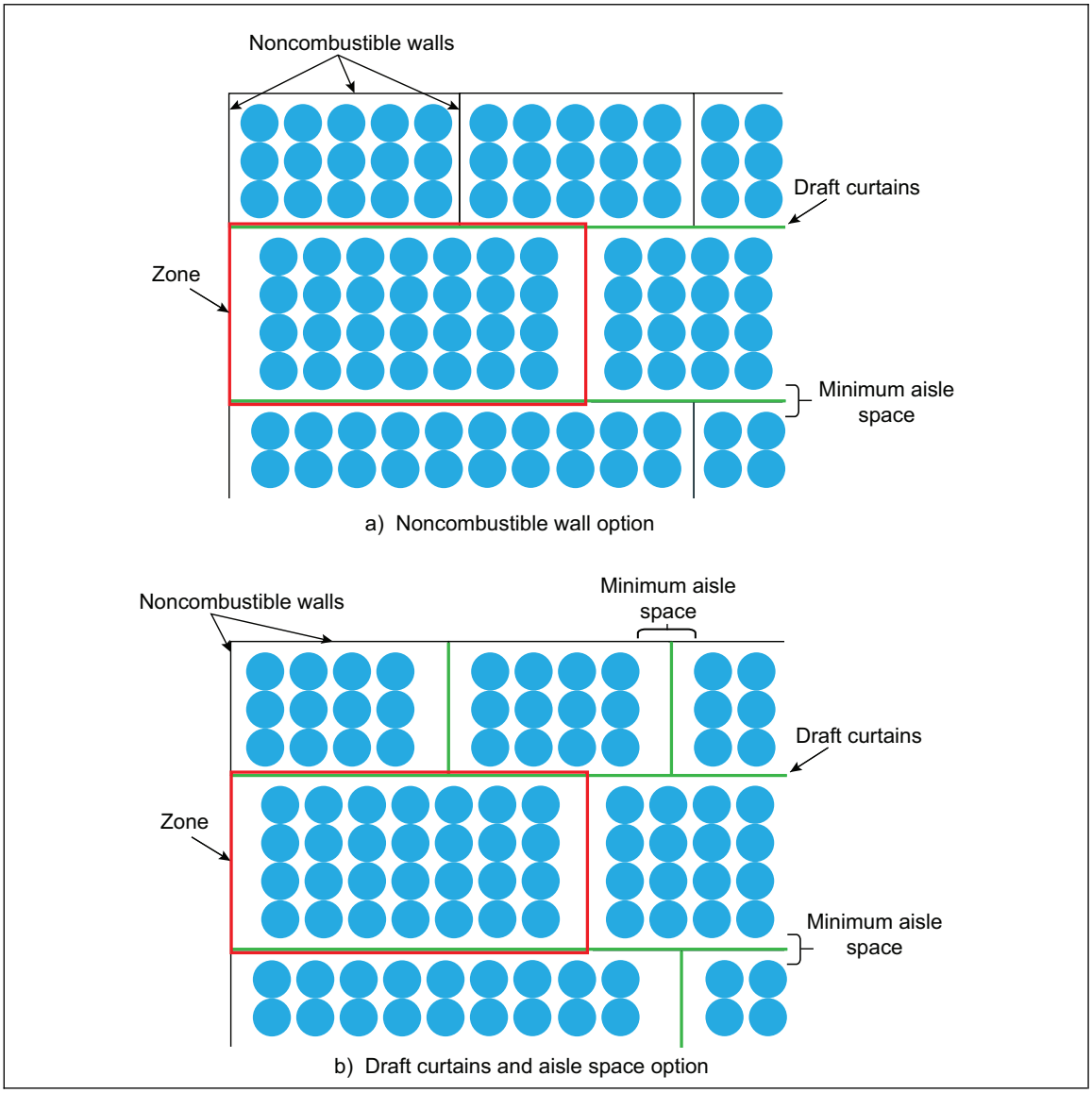

Fig. 2.2.6.1.2. Schematic of storage area separated into zones for RP 1, a) using noncombustible walls and b) using draft curtains and aisle spaces

a. The demand area includes all sprinklers located over a zone and within the bounds of the surrounding walls and/or draft curtains.

b. The maximum zone size and resulting water demand cannot exceed the available water supply.

c. Zones do not have to be square or the same size, provided the minimum pressure requirements are met for each sprinkler within the zone.

Table 2.2.6.1.2. RP 1 Paper Storage Protection

Protection for On-Side, On-End in a Semi-Standard or Standard Array[Note 1]			
Maximum Ceiling Height ft (m)	Maximum Storage Height ft (m)	Wet Sprinkler System, Design Pressure, psi (bar)	
		Pendent, 160°F (70°C), Quick Response	
		K16.8 (K240)	K22.4 (K320)
40 (12.2)	27 (8.2)	90 (6.2)	60 (4.1)

Note 1. Refer to Appendix A for definitions of array types.

2.2.6.2 Protection of RP 2 Paper Stored On-Floor

2.2.6.2.1 Refer to Table 2.2.6.2.1 for wet system protection of RP 2 paper using storage sprinklers where the paper is stacked on-side or on-end in a standard or open array.

2.2.6.2.2 When wet pipe sprinkler systems are impractical, refer to Sections 2.2.3 and 2.2.6.2.3.

2.2.6.2.3 If the storage is protected with a dry sprinkler system, increase the number of sprinklers recommended in Table 2.2.6.2.1 by 50%, not to exceed a maximum of 70 sprinklers. This only applies to RP 2 paper stored up to 30 ft (9.1 m) under a 40 ft (12.2 m) ceiling.

Table 2.2.6.2.1. RP 2 Roll Paper Storage Protection

Protection for On-End in a Standard or Open Array[Note 1, 2]								
Maximum Ceiling Height, ft(m)	Maximum Storage Height, ft (m)	Wet Sprinkler System, Number of Sprinklers @ psi (bar)						
		Pendent, 160°F (70°C), Quick Response						
		Standard Array				Open Array		
		K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K25.2 (K360)	K14.0 (K200)	K16.8 (K240)	K25.2 (K360)
20 (6.1)	15 (4.5)	30 @ 15 (1.0)	12 @ 50 (3.4)	12 @ 35 (2.4)		24 @ 50 (3.4)	24 @ 35 (2.4)	
25 (7.6)	20 (6.1)	35 @ 30 (2.1)	12 @ 50 (3.4)	12 @ 35 (2.4)		24 @ 50 (3.4)	24 @ 35 (2.4)	
35 (10.7)	30 (9.1)	45 @ 30 (2.1)	12 @ 75 (5.2)	12 @ 50 (3.4)		24 @ 75 (5.2)	24 @ 50 (3.4)	
40 (12.2)	20 (6.1)		12 @ 75 (5.2)	12 @ 50 (3.4)		24 @ 75 (5.2)	24 @ 50 (3.4)	
40 (12.2)	30 (9.1)		18 @ 75 (5.2)	18 @ 50 (3.4)		27 @ 75 (5.2)	27 @ 50 (3.4)	
60 (18.3)	30 (9.1)				9 @ 100 (6.9)			12 @ 100 (6.9)
60 (18.3)	40 (12.2)				15 @ 120 (8.3)			20 @ 120 (8.3)

Note 1. Refer to Appendix A for definitions of array types.
Note 2. For shaded protection points, see Section 2.2.6.9 for water supply design.

2.2.6.3 Protection of RP 3 Rolled Paper Stored On-Floor

2.2.6.3.1 Refer to Table 2.2.6.3.1 for wet system protection of RP 3 paper using storage sprinklers where the paper is stacked on-side or on-end in a standard or open array.

2.2.6.3.2 When wet pipe sprinkler systems are impractical, refer to Section 2.2.3 and 2.2.6.3.3.

2.2.6.3.3 If the storage is protected with a dry sprinkler system, increase the number of sprinklers recommended in Table 2.2.6.3.1 by 50%, not to exceed a maximum of 70 sprinklers. This only applies to RP 3 paper stored up to 25 ft (7.6 m) under a 40 ft (12.2 m) ceiling.

Table 2.2.6.3.1. RP 3 Roll Paper Storage Protection[Note 1]

Protection for On-Side or On-End RP 3											
Ceiling Height, ft (m)	Storage Height, ft (m)	Wet System Sprinklers, Number of Sprinklers @ psi (bar)									
		Pendent, 160°F (70°C), Quick Response									
		Standard Array					Open Array				
		K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K22.4 (K310)	K25.2 (K360)	K11.2 (K160)	K14.0 (K200)	K16.8 (K240)	K22.4 (K310)	K25.2 (K360)
20 (6.1)	15 (4.5)	20 @ 7 (0.5)	20 @ 7 (0.5)	20 @ 7 (0.5)			30 @ 7 (0.5)	30 @ 7 (0.5)	30 @ 7 (0.5)		
25 (7.5)	20 (6.1)	25 @ 7 (0.5)	25 @ 7 (0.5)	25 @ 7 (0.5)			38 @ 7 (0.5)	38 @ 7 (0.5)	38 @ 7 (0.5)		
30 (9.1)	25 (7.6)	35 @ 15 (1.0)	12 @ 50 (3.4)	12 @ 35 (2.4)			53 @ 15 (1.0)	24 @ 50 (3.4)	24 @ 35 (2.4)		
40 (12.2)	25 (7.6)	25 @ 50 (3.4)	12 @ 75 (5.2)	12 @ 50 (3.4)			38 @ 50 (3.4)	24 @ 75 (5.2)	24 @ 50 (3.4)		
60 (18.3)	42 (12.8)			20 @ 50 (3.4)	12 @ 75 (5.2)or 18 @ 50 (3.4)					15 @ 75 (5.2) or 28 @ 50 (3.4)	
80 (24.4)	62 (18.9)				10 @ 120 (8.3) or 15 @ 110 (7.6) or 20 @ 100 (6.9)					12 @ 120 (8.3) or 18 @ 110 (7.6) or 24 @ 100 (6.9)	

Note 1. This table applies to all array types. Refer to Appendix A for definition of array types.
Note 2. For shaded protection points, see Section 2.2.6.9 for water supply design.

2.2.6.4 Roll Paper Wrapped in Plastic

2.2.6.4.1 Protect plastic-wrapped roll paper the same as unwrapped paper. This also applies where there is a layer (or several layers) of expanded plastic padding between the outer plastic layer and the paper with a total thickness of expanded plastic not to exceed 3/8 in. (9.5 mm).

2.2.6.4.2 Protect plastic and wax-coated or plastic laminated RP 2 or RP 3 paper, per Table 2.2.6.2.1 and Table 2.2.6.3.1 respectively using minimum K14.0 (K200) or greater pendent sprinklers.

2.2.6.5 Roll Paper Wrapped in RP 3

2.2.6.5.1 RP 2 paper can be protected as RP 3 paper in accordance with Section 2.2.6.3 if wrapped on the sides only (belly wrap) or on both the sides and ends (cocoon wrap).

2.2.6.5.2 RP 1 paper can be protected as RP 3 paper in accordance with Section 2.2.6.3 only if wrapped on both the sides and ends (cocoon wrap).

2.2.6.5.3 If RP 1 paper is wrapped on the sides only (belly wrap), protect standard, semi-standard or open array in accordance with Table 2.2.6.5.3.

Table 2.2.6.5.3. Belly-Wrapped RP 1 Paper Storage Protection

Protection for On-End Belly Wrapped RP 1 in a Standard, Semi-Standard or Open Array				
		Wet Sprinkler System, Number of Sprinklers @ psi (bar)		
Max Ceiling heigh tft (m)	Max Storage height ft (m)	Pendent, 160°F (70°C), Quick Response		
		K14.0(K200)	K16.8(K240)	K25.2(K360)
25 (7.6)	20 (6.1)	24 @ 50 (3.4)	24 @ 35 (2.4)	24 @ 30 (2.1)
35 (10.7)	30 (9.1)	24 @ 75 (5.2)	24 @ 50 (3.4)	24 @ 45 (3.1)
40 (12.2)	30 (9.1)	27 @ 75 (5.2)	27 @ 50 (3.4)	27 @ 45 (3.1)
65 (20)	25 (7.6)			12 @ 80 (5.5)
	30 (9.1)			12 @ 100 (6.9)
	35 (10.7)			12 @ 120 (8.3)
				18 @ 100 (6.9)
				24 @ 80 (5.5)

2.2.6.5.4 Cocoon or belly wrap the rolls as follows:

A. When storing ≤ 30 ft (9.1 m), wrap the rolls with a minimum of 2 layers of RP 3.

B. When storing ≥30 ft (9.1 m), wrap the rolls with a minimum of 4 layers of RP 3.

2.2.6.6 Axial Rod and Rack Storage of Roll Paper

2.2.6.6.1 Protect rack storage of RP 1 paper stored on-end or on-side in accordance with Data Sheet 8-9, scheme 8-9A. Rack structural design should consider the weight of fully wetted rolls to determine adequate design capacity.

RP 1 paper is designed to absorb water, and can absorb many times its weight if exposed to sprinkler water discharge. In a fire, this weight will be added to the rack, and will need to be accounted for to prevent rack collapse and further damage.

2.2.6.6.2 Protect rack storage of RP 2 and RP 3 paper, on-end or on-side, as a Class 3 Commodity, or as cartoned unexpanded plastic if stored on Non-FM Approved plastic pallets, in accordance with Data Sheet 8-9. The modular in-rack sprinkler designs given in 8-9 are not acceptable for roll paper fire protection.

2.2.6.7 Small Hose Connections

2.2.6.7.1 Where small hose (1-1/2 in. [38 mm]) stations are provided, space them to allow full coverage of the area being protected. Add a water demand of 50 gpm (190 L/min) to the combined sprinkler and hydrant demand for a single hose station. Add a water demand of 100 gpm (380 L/min) when more than one hose station is provided.

2.2.6.8 Hose Demand and System Duration

2.2.6.8.1 Provide a minimum 500 gpm (1890 L/min) for hose stream demand and a sprinkler system duration of at least 120 minutes. Add the hose stream allowance to the sprinkler demand at the point of connection.

2.2.6.9 Water Supply Design

2.2.6.9.1 For RP 2 and RP 3 papers with **blue** highlighted protection points, design the water supply to remain at or above design end head pressure throughout the fire duration. Options to meet this recommendation include, but are not limited to, the following:

A. Automatic pre-start of the fire pump using an FM Approved Air Aspirating VEWFD system.

B. A pressurized tank designed to boost the system pressure during the initial stage of the fire until the fire pump can come up to speed, while keeping the hydraulically most remote sprinkler above the minimum design pressure.

C. Large industrial fire protection underground grid, elevated storage tank, constantly running jockey pump, or a combination thereof, capable of providing a water supply equivalent to the options above.

This approach ensures the hydraulically most remote ceiling sprinkler does not drop below minimum design pressure at any time during the fire, even if waiting for a fire pump to start. There may be other options or methods that can be developed and used if designed by a competent hydraulic design professional. See Section 3.0 for additional information.

2.3 Equipment

2.3.1 Interlock all automatic guided vehicles (AGV) to stop operating upon actuation of the fire alarm system.

2.3.2. Interlock overhead cranes to automatically move away from the fire area upon actuation of the fire alarm system. Also provide one or more means of manually moving the cranes, such as emergency push buttons located at accessible remote locations (e.g., control room, security station).

2.3.3 Consider the impact of automated material handling methods (e.g., AGVs, overhead cranes) on the roll paper storage array configuration. Certain equipment may be unable to butt rolls together, resulting in an open array.

2.4 Human Element

2.4.1 Establish a pre-incident plan in cooperation with the local fire service. See Data Sheet 10-1, *Pre-incident and Emergency Response Planning*, for general guidelines related to a pre-incident plan.

2.4.2 Cleanup efforts will require damaged material be removed from the building. As the paper is moved, especially with RP 1, smoldering portions may be uncovered causing the fire to flare up. Hose lines should be available to extinguish any fires.

2.4.3 Train and authorize the emergency response team to move overhead cranes within the roll paper storage area during a fire event. Include details of this authorization in the site emergency response plan in accordance with FM Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*.

3.0 SUPPORT FOR RECOMMENDATION

3.1 Roll Paper Fire Behavior

Roll paper storage presents a unique challenge for fire protection. Under most storage conditions, the fire growth rate and the resulting heat release rate increase rapidly as compared to scenarios with open-frame, rack-storage commodities. The fire behavior of roll paper is dependent on several parameters, including the flammability and absorption characteristics of the paper as well as the storage configuration of the rolls. The following sections provide information to assist understanding of how multiple parameters contribute to the roll paper fire hazard.

3.1.1 Classification of Roll Paper

Previous versions of this data sheet classified papers by basis weight into three categories: lightweight, medium-weight, and heavyweight. However, FM research suggest there should be more to the classification of paper than just basis weight. Therefore, the term “lightweight paper” has been replaced with the term “absorbent paper” and given a classification of RP 1. “Medium-weight paper” and “heavyweight paper” are now referred to as “hard-surface” papers and classified as RP 2 and RP 3 per Section 2.2.1.1.

Absorbent paper, also known as tissue or crepe paper, has properties that affect fire growth and suppression behavior very differently from those of hard-surface paper. Absorbent paper is designed to soak up liquid, and has a low ignition energy due to its relatively low bulk density (weight/volume) compared to hard-surface paper. Due to its absorbent properties, this type of paper soaks up sprinkler water, preventing it from effectively pre-wetting adjacent rolls.

Because hard-surface papers do not soak up water the way absorbent papers do, sprinkler water is allowed to flow freely along the surface of the stored commodity and reach the burning region, as well as pre-wet adjacent rolls, limiting lateral fire spread.

FM has conducted a series of intermediate-scale freeburn, and water suppression tests for representative hard-surface papers, including lightweight (a hard-surface paper with a basis weight as low as 8 lb/1000 ft^2, now considered RP 2), medium weight (RP 2), and heavyweight (RP 3) with varying inert content, to assess the roll paper classification for sprinkler protection. The conclusion of this research indicates that both paper density per area (basis weight), and inert content (as a percentage by weight, dry basis) influence the fire hazard and suppression behavior of roll paper.

As the percentage of inert content increases with the same basis weight, the fire hazard decreases, and the suppression effectiveness increases. To determine the paper classification, there are two pieces of information needed: the basis weight, and the percentage of inert content of the paper. Appendix A provides additional information on the definitions of these two variables.

3.1.2 Storage Arrangement

3.1.2.1 On-End Storage

Roll paper stored on-end exhibits rapid fire growth along continuous vertical flue spaces that produces a strong fire plume. For this reason, all on-end storage of roll paper presents a challenge to automatic sprinkler protection. Open arrays allow for flame spread in all directions, which increases the heat release rate, plume strength, and overall fire area. Standard arrays tend to limit the flame spread to along the ignition flue, resulting in a lesser fire hazard than the open array. However, should the fire start at or reach the face of

the storage, both standard and semi-standard arrays can exhibit rapid flame spread along the face of the array with the burning paper exfoliating in the outer stacks allowing the fire to spread into and down adjacent flues.

As storage heights increase, the fire hazard also increases, and sprinkler protection systems require larger orifice sprinklers at high pressures to provide enough downward thrust to overcome the fire plume. At storage heights above 30 ft (9.1 m) it becomes critical for the fire protection system to remain at or above the design pressure upon initial sprinkler activation and throughout the duration of fire suppression. See Section 2.2.6.9 for guidance on ensuring this design pressure is maintained. For such array heights, the heat release rate increases so rapidly that a minor delay in providing suppression water at the design pressure can result in excessive sprinkler activation, which will overtax the system and allow uncontrolled fire spread.

3.1.2.2 On-Side Storage

On-side storage arrangements prevent unwinding and peeling in a fire. Rolls stored on-side may be nested between rolls of a lower tier or separated by dunnage placed between tiers. Where dunnage is used, there is opportunity for fire to burrow into a pile and make extinguishment more difficult than for nested rolls. Such a fire is well shielded from firefighting efforts, can involve a large portion of the storage, and can become quite severe in vertical flue spaces.

3.1.2.3 Storage on Axial Rods

Paper is sometimes supported horizontally on racks by rods that run axially through the roll cores. These arrangements have the same general fire characteristics as separated vertical stacks because of separation between rolls that allows the paper to peel or unwind.

3.1.3 Hazard Mitigation Techniques

Fire spreading through roll paper storage quickly burns through the outer ply. Unless there is some arrangement to prevent it, paper will unwind or peel from the rolls. This process is typically called “exfoliation.” Exfoliated paper rapidly increases burning surfaces and the fire spreads by contact with adjacent piles. During this process, the rolls continually shed outer layers that have been wetted by sprinkler discharge, exposing dry paper beneath and allowing continued fire spread.

3.1.3.1 Closed Flue Spaces

Butting rolls against each other limits the flame spread and prevents paper from exfoliating, reducing overall fire severity.

3.1.3.2 Banding

Although industry has been moving away from metal banding, it is still a viable means of reducing fire hazard potential in open arrays. Metal bands greatly reduce exfoliation; such bands may be the ones used to protect roll ends during shipment or those with slide fasteners. Steel baling wire applied tightly by hand is also effective. Fire testing has shown that storing rolls in a standard array has a similar effect as banding.

3.1.3.3 Wrapping

The fire hazard can be reduced by wrapping rolls with a lower-hazard paper. For instance, RP 2 paper can be protected as RP 3 when wrapped with RP 3 paper. Cocoon wrapping RP 1 with RP 3 has the effect of reducing the fire hazard as well as limiting water absorption, which enhances water transport and enables effective pre-wetting. Wrapping RP 1 with RP 3 around the sides only (belly wrap) is an alternative solution to totally encasing the roll; however, water absorption on top of the rolls adversely affects water transport along the sides of the rolls. The sprinkler protection must then be increased to compensate. See Section 2.2.6.5.3 for protection guidance of RP 1 that is belly wrapped.

3.2 Disadvantages of Upright Sprinklers

For many years, upright sprinklers have been installed for the protection of roll paper. However, upright sprinklers have some disadvantages compared to pendent sprinklers, and are therefore no longer recommended for the protection of roll paper. Upright sprinklers have inherent obstructions due to their placement above the sprinkler branch lines. Fires involving roll paper storage require a large amount of water to reach the seat of the fire with as few obstructions as possible to ensure prompt control of the fire. Using

upright sprinklers allows the fire to grow larger because some of the effective water is obstructed by the sprinkler piping itself. This leads to larger sprinkler operating areas, as well as larger fires resulting in greater damage.

3.3 Lack of Standard Sprinkler Protection Options for Open Array RP 1

Testing has shown that open array storage of RP 1 paper cannot be protected by standard sprinkler protection alone. RP 1 paper has four qualities that significantly challenge standard sprinkler protection when stored in this arrangement:

1. The absorptivity of the paper prevents effective water flow down the parent rolls as most sprinkler water is absorbed into the tops of the rolls and limited pre-wetting occurs near the bottom of the storage.
2. RP 1 paper ignites very easily, leading to extremely rapid vertical and lateral fire spread.
3. Exfoliation of the outer paper layers continuously exposes dry, fresh fuel for continuous fire growth and spread.
4. During a fire, significant amounts of tissue material can shed from the rolls, become lofted by the fire plume, and when wetted by sprinkler spray can stick to and coat the sprinklers at the ceiling, leading to delayed or skipped sprinkler activations.

Due to the rapid lateral fire spread and potential for sprinkler skipping, a fire will quickly spread through the flue spaces faster than automatic sprinklers can react, resulting in an uncontrolled fire.

Fire tests have shown that even with very prompt sprinkler activations, these four factors combine to allow the fire to find “dry spots” in the roll paper array to continue fire spread. By the time sprinklers over a new fire area activate, the fire will typically find another path and continue spreading. In fire tests conducted with RP 1 paper in an open array, the fire spread throughout the entire array, opening many sprinklers, which were not able to control flame spread.

3.4 Water Supply Design

Fire testing has shown that in cases where open array roll paper is stored above 30 ft (9.1 m) and protected with K16.8 (K240), K22.4 (K310), or K25.2 (K360) sprinklers, many sprinklers can operate during the beginning stages of the fire in a very short period of time. For example, in one test, thirteen K25.2 (K360) QR sprinklers operated in 3 seconds. The testing showed that the pressure in the system dropped dramatically as these sprinklers opened. If the system pressure drops too low, the sprinklers will not have the same effect on the fire and may allow it to spread and open more sprinklers, overtaxing the sprinkler system. Therefore, maintaining the sprinkler system at or above the sprinkler design pressure throughout the entire fire event is very important.

An example of this can be seen in Figure 3.4, which shows sprinkler system pressure as a function of operating sprinklers and the associated heat release rate. In this example, the sprinklers were supposed to meet the design pressure for the duration of the test for protection of RP 3. After the initial sprinkler operation at time=0, the pressure declines and the heat release rate (HRR) increases. As the system attempts to bring the pressure back up to the operational set-point, the HRR continues to increase, more sprinklers operate, and the pressure begins to decrease again.

Because the sprinkler system could not maintain the operating pressure at the design pressure, the sprinkler response is ineffective at controlling the HRR, resulting in an uncontrolled fire. These fire dynamics are not specific to roll paper storage, but the rate at which the pressure drops and sprinklers open is. Figure 3.4 shows that in a matter of 9 seconds, 35 sprinklers operated but had little effect on the growth and HRR of the fire. This example demonstrates the importance of water supplies being capable of maintaining design pressure throughout the duration of the fire event.

3.5 Rack Storage Protection

Paper manufacturers are always looking for additional storage capacity for parent rolls, and one of the answers to that need is rack storage, as well as automated rack storage and retrieval systems. Axial rod, tambour, and rack storage protection arrangements are very similar, and consist of rolls that are stored off the floor on a structural frame.

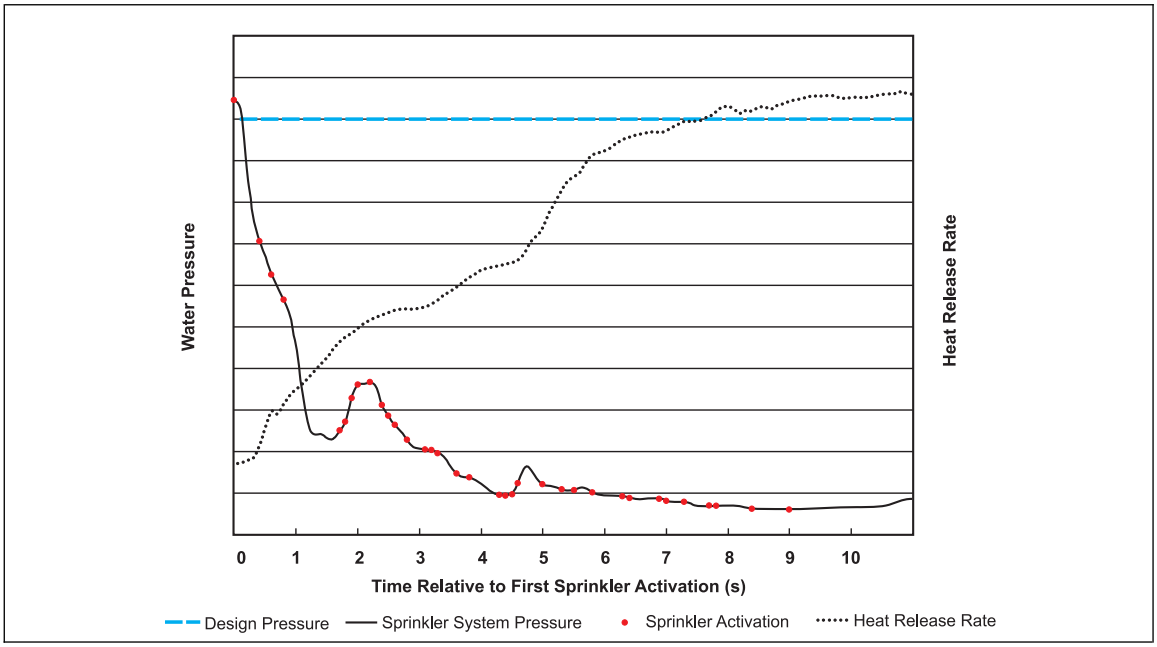

Fig. 3.4. Time/pressure plot vs. heat release rate for RP 3

Based on conclusions from recent open array storage testing, the arrangement of RP 1 in racks will require substantial sprinkler protection as well. Due to the rate of fire spread, ability of the paper to absorb lots of water, and, ease of ignition, a singular method of protecting RP 1 has been established based on FM Data Sheet 8-9. The intent is to ensure the fire spread does not extend vertically or horizontally without prompt activation of sprinkler protection. Scheme 8-9A from Data Sheet 8-9 ensures this protection. This application is specific to large rolls, such as parent rolls. RP 1 paper packaged in consumer packaging is classified in accordance with Data Sheet 8-1 and protected in accordance with Data Sheet 8-9.

RP 2 and RP 3 have historically been treated as a class 3 commodity. This is an adequate commodity classification because these rolls take longer to become involved in a fire, allowing sprinkler protection time to react and control vertical and horizontal fire spread. This document does not recommend the use of Data Sheet 8-9 modular in-rack sprinkler designs, in which hydraulic balancing of the in-rack and ceiling-level sprinkler systems is not required. For roll paper, the ceiling level and in-rack level fire protection needs to be balanced to ensure they can control fire spread.

3.6 Loss History

3.6.1 Illustrative Losses

3.6.1.1 Sprinkler System Controls RP 3 Roll Paper Fire

A fire in a diesel-fueled lift truck spread to roll paper in a warehouse section of a large paper mill. The RP 3 rolls were stored unbanded, on-end, in a standard array 26 to 30 ft (7.9 m to 9.1 m) high. The building was 44 ft (13 m) high at the peak and 39 ft (12 m) at eaves. Automatic sprinkler protection was provided at ceiling level with K8 (K120), 286°F (140°C) upright sprinklers on a 84 ft^2 (7.8 m^2) spacing designed to provide a design density of 0.60 gpm/ft^2 (24 mm/min) over the most remote 4088 ft^2 (380 m^2). This was an increased design area to compensate for the 13 ft (4.0 m) clearance from the top of storage to the roof. The sprinkler design and water supply were determined to be adequate. In all, 46 sprinklers operated over a floor area of 3873 ft^2 (360 m^2). The fire was concentrated in a 2150 ft^2 (200 m^2) to 2690 ft^2 (250 m^2) area, and 3 in. (76 mm) of water accumulated over 77,000 ft^2 (7,200 m^2), soaking rolls that were placed directly on the floor. Including the burned rolls, about 2450 ton (short) (2,200 ton [metric]) of paper was damaged, but it was estimated that 30% of the water-damaged rolls could be salvaged. Damage to the steel frame building was limited to overhead cable trays and nearby electrical cabinets. There was no business impact from this loss.

3.6.1.2 High Intensity Light Bulb and Weak Protection Over RP 1 Rolls

Rupture of a sodium or metal halide light bulb caused a fire that severely damaged a sprinklered building occupied mainly for the storage of RP 1 paper rolls. These rolls were stored on end to a height of 13.5 ft (4.1 m). The metal deck roof, along with steel bar joists, was deformed over an area of 2160 ft^2 (200 m^2). Rolls of paper throughout the building were damaged by fire, smoke, and water. The entire tissue paper mill was shut down for approximately 2.5 hours. Interruption of a power feed shut down the case packing operation for about 13 hours. The fire could have been prevented if the light had been enclosed so as not to allow hot quartz and glass to contact paper rolls. The light ruptured when the quartz arc tube in the high-pressure/ high-temperature, 400 W lamp exploded. Fire damage could have been significantly reduced if sprinklers had been more effective. Sprinkler density was inadequate for the challenge presented.

4.0 REFERENCES

4.1 FM

Data Sheet 1-20, *Protection Against Exterior Fire Exposure*
Data Sheet 1-12, *Ceilings and Concealed Spaces*
Data Sheet 1-42, *MFL Limiting Factors*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 8-1, *Commodity Classification*
Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*
Data Sheet 8-23, *Rolled Nonwoven Fabric Storage*
Data Sheet 10-2, *Emergency Response*

4.2 Other

National Fire Protection Association (NFPA). NFPA 13, *Installation of Sprinkler Systems*.

APPENDIX A GLOSSARY OF TERMS

Absorbent: Paper that can soak up liquid easily. All RP 1 paper is absorbent.

Banded paper: Roll paper that is provided with one or more circumferential metal or plastic bands or metal wires to prevent unwinding.

Butted: When describing roll paper storage arrays, this term means two rolls are touching along one or more circumferential edges, and to meet the intent of this definition, the rolls need to be touching to the height of the stack with no visible gaps.

Closed array: An on-end storage arrangement of roll paper in which roll stacks are butted in all directions. See Figure A-1.

Exfoliation: When the outer layer of paper, being burned, unwraps or peels away from the core of the roll.

FM Approved: A product or service that has satisfied the criteria for FM Approval. Refer to the *Approval Guide*, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Inert content: The noncombustible components of the paper stock mix that typically come from paper coating additive(s). Coatings may have different makeups, including PCC/GCC (precipitated calcium carbonate/ ground calcium carbonate), Kaolin clay (aluminum silicate hydroxyl), latex, starch, and wax. PCC/GCC and kaolin are the most common coatings used in the market and are considered inert. Latex, starch, and wax are combustible and cannot be considered inert. Method to determine inert content:

1. Determine the coating mass fraction (percentage by mass) of the paper to be protected, and whether the coating contains combustible components such as latex, starch, wax etc. If no combustible content is identified, the coating mass fraction can be counted as a percentage of inert content and used in calculating the roll paper classification.

2. If the combustible portion of coating is unknown or unavailable, apply the ash content analysis and use the percentage of ash content as the percentage of inert content. The Tappi T211 om-02 ash content analysis method or the similar ASTM ash analysis D3174-12, which is available through FM Approvals lab and commercial labs, should be used.

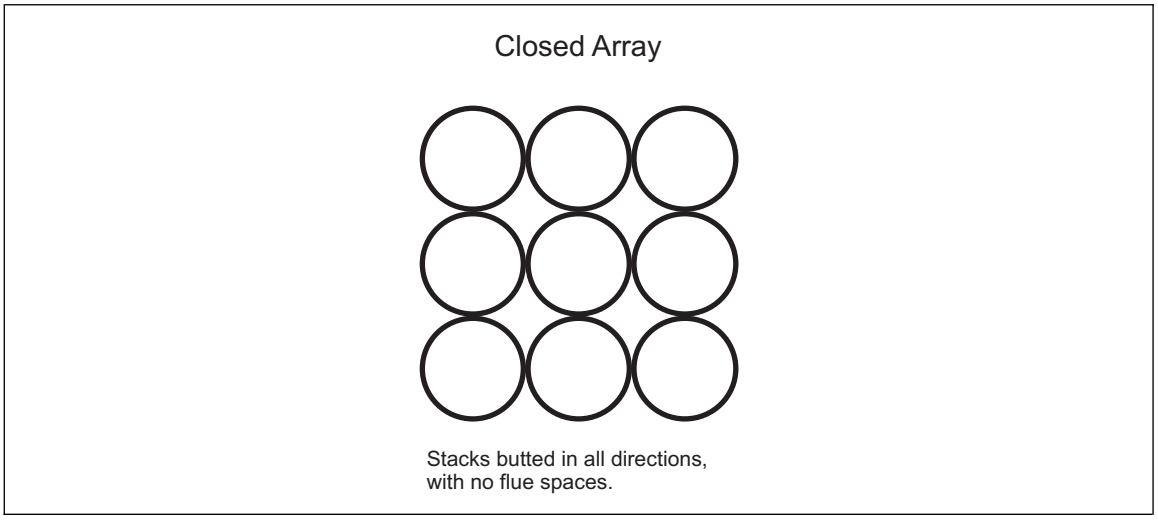

Fig. A-1. Roll paper closed array

3. If the percentage of the combustible portion of the coating is known, this portion should be subtracted from the coating mass fraction to calculate the percentage of inert content.

Open array: An on-end storage arrangement of roll paper in which there is stack spacing allowing flues in all directions. Open array storage is usually found where rolls are not uniform in diameter, or in locations that use automated equipment, such as overhead cranes or automatic guided vehicles, to move the rolls. See Figure A-2.

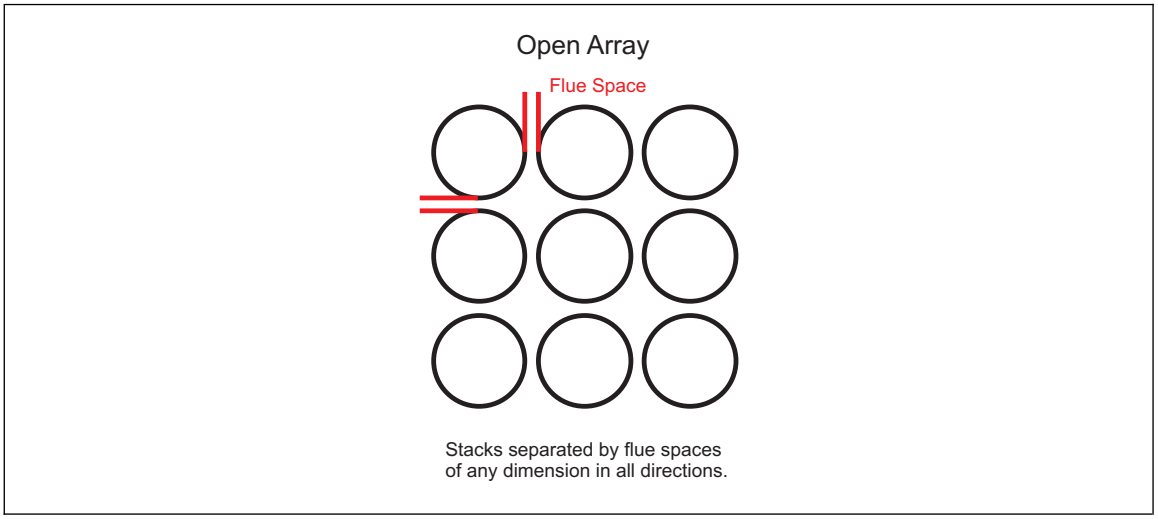

Fig. A-2. Open array roll paper

Plastic-coated paper: Paper with a thin coating such as that found on a milk carton.

Plastic wrapped: A wrapping method consisting of a plastic sheet or bag enclosing the sides and/or ends of roll paper.

RP 1 paper: Paper with an absorbent, fibrous, or gauzy texture regardless of basis weight. Examples include toilet tissue, napkins, crepe, facial tissue, and paper towels.

RP 2 paper: Paper with a hard, smooth, or glossy finish that weighs less than 20 lb/1000 ft^2 (98 g/m^2) with an percentage of inert content below the line given in Figure 2.2.1.3.1-1 or 2.2.1.3.1-2. Examples include newsprint, tablet, computer, envelope, book, butcher, label, bond, magazine, vellum, and bag paper. Examples of papers with basis weights less than 10 lb/1000 ft^2 (44 g/m^2) that are also included are onion skin, catalog paper, fruit wrap, carbon paper, and cigarette paper. Some newsprint may weigh as little as 8.6 lb/1000 ft^2 (42 g/m^2).

RP 3 paper: Paper that weights more than 20 lb/1000 ft^2 (98 g/m^2) regardless of percentage of inert content. RP 3 paper also includes paper that weighs less than 20 lb/1000 ft^2 (98 g/m^2) with an percentage of inert content above the line given in Figure 2.2.1.3.1-1 or 2.2.1.3.1-2. Examples include liner board, corrugating medium, Bristol board, vellum Bristol board, index, cup-board, tag, folding box board, and kraft roll wrappers.

Semi-standard array: An on-end storage arrangement of roll paper which combines aspects of both standard and open storage arrays, where the first two levels of stacked roll paper are in a standard array and the third level of stacked paper is in an open array. For example, uniform diameter rolls are in vertical stacks butted in one direction and separated by any dimension flue space in the other direction for the first two stacked rolls, while the third level of stacked rolls allows for separation of the rolls by any dimension flue space in both directions. See Figure A-3.

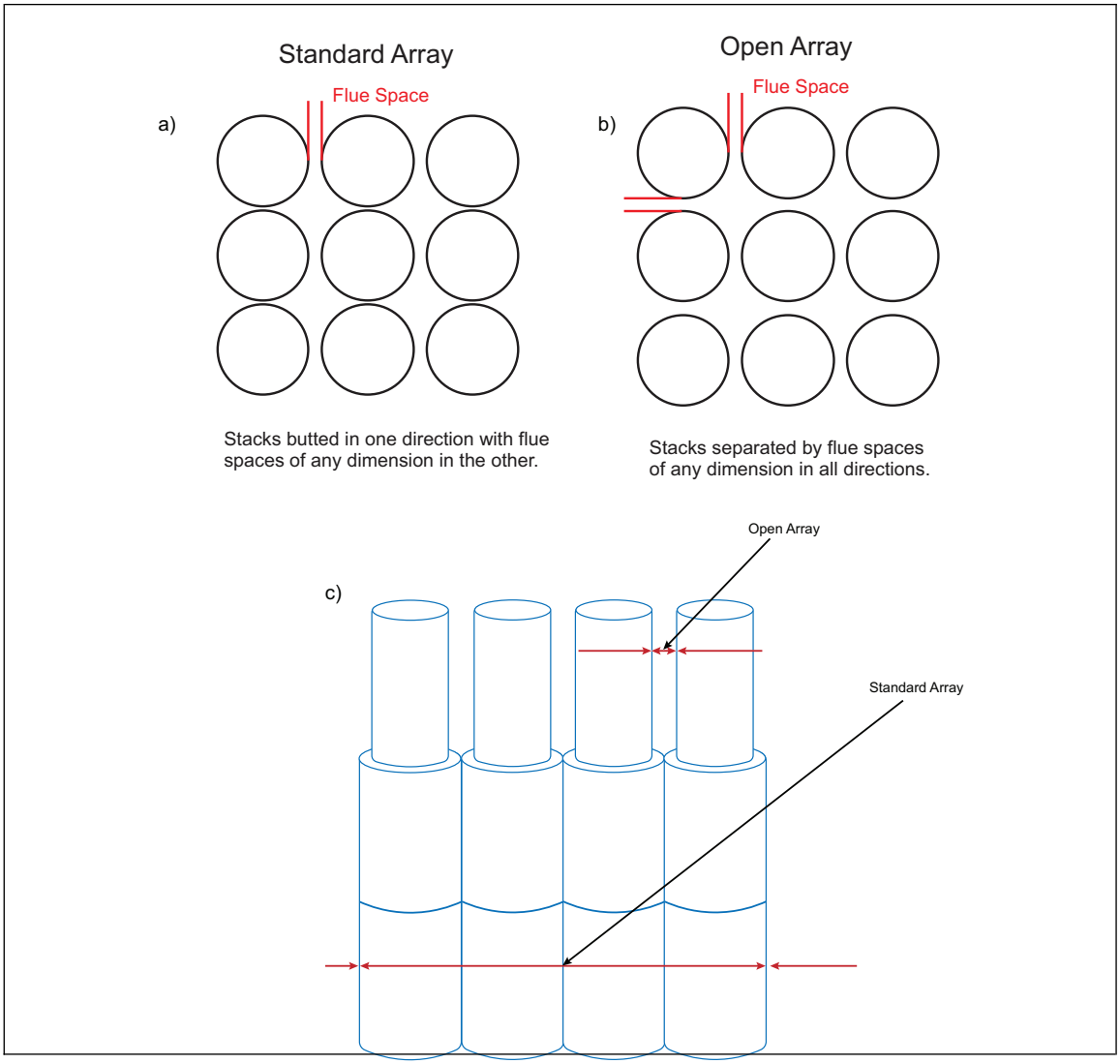

Fig. A-3. Roll paper semi-standard array a) plan view of first two levels of storage, b) plan view of third level of storage, and c) elevation view of storage.

Sprinkler clearance: Clear space maintained between the top of storage and ceiling sprinkler deflectors. Clearance is measured to the sprinklers closest to the peak of sloped roofs.

Standard array: An on-end storage arrangement of roll paper in which uniform diameter rolls are in vertical stacks butted in one direction and separated by any dimension flue space in the other direction. The standard array is usually found where rolls are uniform in diameter and clamp trucks are used. See Figure A-4.

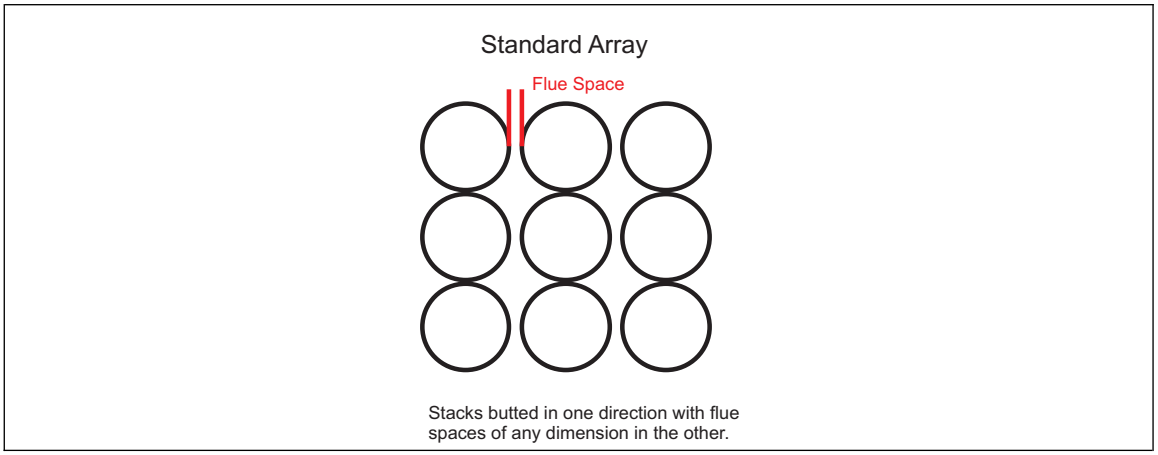

Fig. A-4. Roll paper standard array

Storage height: Maximum height of storage measured from the floor to the top-most level of storage.

Storage, on-side: Paper stored with no structural support. Rolls are laid on their sides, with their diameters perpendicular to the floor. Sometimes on-side rolls are “nested,” where they create a pyramid shape as rolls are stacked on top of each other.

Storage, on-end: Paper stored with no structural support. Rolls are stored with their diameters parallel the ground. With on-end storage, the paper can be arranged in a closed, standard, or open array.

Storage, axial rod: This paper is stored in a similar orientation to on-side, however it is supported by a metal rod, which goes through the center of the roll, and is supported by a structure.

Storage, rack: Paper stored on-side or on-end in a typical rack structure. Rolls can be manually loaded or part of an automatic storage and retrieval system.

Storage, tambour: This is an old term used to describe axial rod storage of mother reels coming directly off the dry end of the paper machine. This is treated as axial rod paper.

Wrapping, belly: A method of covering only the circumferential sides of the outer layer of a roll with plastic wrap or layer(s) of paper of a heavier grade.

Wrapping, cocoon: A method of covering the circumferential sides, top, and bottom of the outer layer of a roll with plastic wrap or layer(s) of paper of a heavier grade.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

January 2023. Interim revision. The following changes were made:

A. Removed allowance of dry-pipe systems for RP 1 protection in Section 2.2.3.

B. Updated manufacturing area RP 1 in-process storage guidance in Section 2.2.5.

C. Reorganized Section 2.2.6 and updated RP 1 on-floor storage protection guidance, including Table 2.2.6.1.2.

D. Expanded RP 1 belly wrapped protection options in Table 2.2.6.5.3.

E. Clarified hose demand and system duration recommendations for wrapped RP 1 in Section 2.2.6.8

F. Added pre-incident plan recommendations to human element in Section 2.4.

G. Added supporting material related to on-end storage of RP 1 in Section 3.1.2.1 and Section 3.3.

H. Added definition of semi-standard array to Appendix A.

October 2019. Interim revision. Minor editorial changes were made for this revision.

April 2019. Interim revision. Added guidance related to the impact of automated material handling methods on the roll paper storage array configuration.

April 2018. The interim revision outlined minor changes to Figures 1a and 1b; other editorial changes.

January 2018. This document has been completely revised. Significant changes include the following:

A. Modified roll paper classification methodology and terminology.

B. Revised guidance for wrapping RP 1 and RP 2 papers.

C. Provided new protection criteria for belly-wrapped RP 1.

D. Updated protection tables for all paper classifications.

E. Replaced sprinkler protection guidance for open array tissue with alternative solutions.

F. Provided new protection criteria for higher storage heights of hard-surface paper.

G. Added guidance to Table 2 and Table 3.

H. Improved guidance for rack storage of rolled paper.

I. Added new protection guidance for water supply design associated with higher roll paper storage heights.

J. Added guidance for human element and interlocks for automated roll handling equipment.

K. Updated support for recommendations, loss history, loss examples, definitions, and reference information.

L. Aligned the format of the document with current data sheet development requirements.

January 2015. Interim revision. Definition of the diffrent array types was improved for clarity.

October 2014. Interim revision. Recommendations 2.2.4.3.4 and 2.2.4.4.4 were improved for clarity.

July 2014. The following major changes were made:

A. Replaced the terms “control-mode density-area (CMDA) sprinkler,” “control-mode specific-application (CMSA) sprinkler” and “suppression-mode sprinkler” with “storage sprinkler.” This terminology is consistent with other FM Global storage data sheets.

B. Changed all ceiling-level sprinkler protection options to a number of sprinklers at a minimum operating pressure (e.g., 20 sprinklers @ 50 psi [3.4 bar]).

C. Revised the protection guidelines for heavy-, medium-, and light-weight rolled paper.

D. Revised the recommendation for banding rolls: the banding of rolls is no longer required when the protection guidelines in this version of DS 8-21 are followed.

E. Revised the protection recommendations for open array storage of medium-weight and heavy-weight paper.

F. Revised the protection recommendations for dry sprinklers systems.

January 2013 (Interim Revision). A protection option for heavyweight paper stored 42 ft (12.8 m) of on-end, standard array (banded or unbanded) under ceilings up to and including 60 ft (18.3 m) high when installed on a wet pipe system has been added to Section 2.3.5. In addition minor editorial changes and clarifications have been made.

May 2008. Clarification was made to Note 1 in Table 8.

January 2008. Specify storage arrangements that are acceptable for the protection recommendations in Table 8, ″Heavyweight Roll Paper Storage Protection, Control Mode, Specific Application Sprinkler.″

January 2003. Recommendations provided for the protection of medium and heavyweight paper with upright suppression mode sprinklers with a K-factor of 16.8 (242). Loss history information was updated.

May 2002. Additional protection guidance was added to Table 7, *Heavyweight Paper Storage Protection.*

May 2001. Recommendations provided for the protection of medium and heavyweight paper with suppression mode sprinklers with a K-factor of 16.8.

January 2001. Additional information is provided to clarify the use of interpolation when determining the design area for heavy and mediumweight paper using control mode, density area sprinklers (sections 2.3.4.2 and 2.3.5.2).

September 2000. This revision of the data sheet includes the following significant changes:

1. Hose stream and total water demand recommendations have been simplified (section 2.3.7).

2. Sprinkler protection tables are subdivided by paper weight and sprinkler type. Within the tables the protection for storage height and building height are listed as a function of sprinkler type (sections 2.3.3, 2.3.4 and 2.3.5).

3. Automatic sprinklers are identified using new classifications. The classifications are: control mode (density/area), control mode (specific application) and suppression mode. Definitions and examples for the classifications are provided in Appendix A.

4. Recommendation for the protection of rack storage of roll paper have been added (section 2.3.1.4).

March 1991. Data Sheet was revised to include protection recommendations using suppression mode sprinklers and large drop (control mode — specific application) sprinklers. Additional guidelines were provided for axial rod storage.

November 1983. Data Sheet revised to include protection criteria based on three different paper classifications. Protection recommendations were provided for rolls wrapped in paper and plastic.