ROLL PAPER STORAGE

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1.0 SCOPE

This data sheet provides loss prevention guidelines for the protection of various grades of roll paper stored on the floor, on-end or on-side. Guidelines are also included for protection of heavyweight and mediumweight roll paper held horizontally by axial rods on supporting structures. Guidelines are also provided for plastic-coated paper, rolled pulp and plastic-wrapped roll paper.

This data sheet does not apply to the storage of rolled nonwoven fabrics, layered pulp with synthetic fillers, polyester or rayon and chemically treated rolled paper.

Protect baled waste paper and small scattered amounts of in-process roll paper storage according to the recommendations in Data Sheet 8-22, *Storage of Baled Waste Paper* and Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*, respectively. Protect solid-piled pulp or palletized baled pulp as a Class 3 commodity according to Data Sheet 8-9, *Storage of Class 1,2,3,4 and Plastic Commodities*. See section 2.1.1.2 for examples of small scattered amounts of in process storage.

1.1 Changes

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 2.6.5. In addition minor editorial changes and clarifications have been made.

1.2 Superseded Information

The January 2013 revision of this data sheet supersedes the January 2008 revision of the document. This revision also supersedes the recommendations in Engineering Bulletin 01-12, *Heavy-Weight Roll Paper Protection.*

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 Recommended Safe Practices

2.1.1.1 Small Quantities of Storage. The following are examples of small amounts of storage. In-process storage of 500 ft^2 (46 m^2) of lightweight roll paper or 1000 ft^2 (93 m^2) of meduimweight or heavyweight roll paper 5 ft (1.5 m) high. Three or four stacks of any grade of roll paper stored 15 ft (4.6 m) with no combustibles within 15 ft (4.6 m) of the stacks. Although fire from the burning stacks may cause as many sprinklers to operate as a larger amount of burning paper, the fire will not spread unless other combustibles are nearby. Another example is 200 ft^2 (18 m^2) of roll paper in area to a height of 10 ft (3 m).

2.1.1.2 There is no substitute for a well-trained emergency organization. Early detection and effective action by personnel during a roll paper fire can greatly reduce fire and water damage. Controlling possible ignition sources, maintaining proper aisle spacing and practicing good housekeeping are other recommended safe practices. Aisle spaces are an advantage in manual fire fighting, clean-up and salvage operations. Adequate width may vary, but where large objects such as rolled paper are being stored, at least an 8 ft (2.4 m) aisle is recommended.

2.1.1.3 When fires involve lightweight papers, especially paper with an absorbent texture, observe caution in fighting such a fire. The fire spreads horizontally very rapidly, and rolls may collapse after absorbing sprinkler water. The rolls can weigh 4000 lbs (1816 kg) when dry, and could exceed 6000 lbs (2724 kg) after absorbing sprinkler water.

2.2 Construction and Location

2.2.1 Steel Protection

2.2.1.1 When sprinkler systems are installed in accordance with this data sheet, fire protection of roof or column steel is not required.

2.2.2 False Ceilings

2.2.2.1 When a false ceiling is constructed ensure that proper clearance is achieved (see Section 2.3.2.7, Excessive Clearance). Install sprinklers below the false ceiling designed in accordance with the recommendations in this data sheet. Install additional sprinklers at roof level, within the concealed space, when the roof or false ceiling consists of combustible construction or there are combustibles within the space. Water demands from sprinklers at roof level, within the concealed space do not need to be available simultaneously with the water demands from sprinklers below the false ceiling.

2.2.2.2 Construct false ceilings, capable of withstanding temperatures above 1000°F (540°C) for up to 10 minutes and uplift velocity pressures of at least 3 lb/ft^2 (0.14 kPa). Materials suitable for such a purpose include ⅜ in. (0.95 cm) plywood, ⅜ in. (0.95 cm) gypsum board, corrugated or sheet steel, or mineral tile. Sheets of these materials can be mechanically fastened to the underside of existing framework, or supported on framework from above or below.

2.2.2.3 If the false ceiling is hung from existing roof framework verify that the roof can support the additional dead load.

2.2.3 Roofs

2.2.3.1 Flat ceilings are preferable to peaked ones. Peaked ceilings channel the heat of the fire upward toward the peak, causing sprinklers outside the immediate fire area to operate. A ceiling slope up to and including 2 in./ft (168 mm/m) is acceptable for all sprinkler types.

2.2.4 Heat and Smoke Vents

2.2.4.1 FM Global recommended protection is based on automatic heat and smoke vents not being provided. Fire tests have not shown automatic heat and smoke vents to be cost effective, and they may increase the water demand. Arrange permanent heat and smoke vents for manual operation. If local codes require that heat and smoke vents be arranged for automatic operation, use the types and operating temperatures in Table 1.

2.2.4.2 As an alternative to automatic heat and smoke vents, smoke removal can be achieved through eaveline windows, doors, monitors and non-automatic exhaust systems (gravity and mechanical) or manually operated heat and smoke vents. In addition, fire fighters may cut holes in steel and wood roofs and also use positive pressure ventilation or smoke exhausters to remove smoke.

Table 1. Heat and Smoke Vent Types and Operating Temperatures

Sprinkler	*Acceptable Vent*	*Vent Operating Temperature*
Suppression Mode	Fusible link operated (Drop-out type vent not acceptable)	Minimum 360°F(182°C), with standard response links.
Control Mode, Special Application	Fusible link operated	Minimum 360°F(182°C), with standard response links.
	Drop-out type	As Approved
Control Mode, Density/Area	Fusible link operated	Minimum one temperature rating higher than ceiling sprinklers using standard response links
	Drop-out type	As Approved

2.2.4.3 Local authorities may require that vent operating temperature be a specific number of degrees higher than the sprinklers' temperature rating. In such cases select a vent link temperature rating that meets both FM Global and local code recommendations. When the FM Global link temperature ratings cannot be satisfied, install an additional sprinkler under the center of the vent. It is not necessary to include the additional sprinkler in the water demand.

2.2.5 Water Damage Protection

2.2.5.1 Roll paper is very susceptible to damage from water used in fire fighting or from ‘‘mill-use’’ sources. Evaluate the storage, the building construction and the type of material handling equipment to determine if there is an effective method of minimizing water damage. Skids or pallets may be used to raise smaller rolls

above floor level. Note, they may not be strong enough to support the larger rolls that can weigh as much as 5000 lbs (2300 kg) each. Also skids or pallets may not be a practical solution that is compatible with the storage and handling methods at the location.

2.2.5.2 Trenches or floor drains are also used as an effective means to minimize water damage. For information about floor drainage see Data Sheet 1-24, *Protection Against Liquid Damage*. The need for drainage will depend on the storage and material handling equipment. Trenches or drains may not be a cost effective or practical solution for existing storage locations.

2.2.5.3 Water damage is most severe with lightweight papers such as tissue, if proper protection is not provided. Water accumulations on the floor will saturate the bottom rolls, causing them to soften, leading to eventual toppling of the piles. Trenches are preferred over floor drains for tissue storage because drains may plug with clumps of wet tissue paper. Trenches dividing floor areas into approximately 10,000 ft^2 (930 m^2) areas will generally provide adequate protection.

2.2.5.4 Plastic wrapping around the entire roll can significantly reduce the water damage.

2.2.6 Allowable Loads

2.2.6.1 Design upper floors used for roll paper storage to hold the possible additional weight from water absorption, which will vary between types of paper. Roll tissue paper may absorb up to three times its weight from sprinkler discharge exposure of one hour. Higher absorption may be anticipated with longer discharge durations and inadequate drainage or skidding. However, keep in mind that neither total absorption nor the confinement of a large depth of water are likely.

2.3 Protection

2.3.1 General Protection Guidelines

This section provides guidelines and recommendations for determining protection for various methods of paper storage and packaging methods.

2.3.1.1 Rolls Wrapped with Heavyweight Kraft Paper

2.3.1.1.1 Rolls of lightweight or mediumweight paper can be protected as heavyweight paper provided one of the following wrapping methods is used.

1. The sides and ends are wrapped with a minimum of a single layer of heavyweight paper weighing at least 40 lb/1000ft^2 (195g/m^2).

2. The sides and ends are wrapped with a minimum of two layers of heavyweight paper weighing at least 20 lb/1000ft^2 (98g/m^2).

3. The sides are wrapped with a minimum of a single layer of heavyweight paper weighing at least 40 lb/1000ft^2(195g/m^2) and are banded with steel straps.

4. The sides are wrapped with a minimum of two layers of heavyweight paper weighing at least 20 lb/1000ft^2 (98g/m^2) and are banded with steel straps.

2.3.1.2 Plastic Wrapped Paper

2.3.1.2.1 Protect plastic-wrapped roll paper the same as unwrapped paper. Design the sprinkler demand areas and densities for plastic-wrapped roll paper based upon the paper itself, without any adjustment for the plastic wrapping.

2.3.1.2.2 The above also applies where there is a layer (or several layers) of expanded plastic padding between the outer plastic layer and the paper; in most cases, the total thickness of expanded plastic will not exceed ⅜ in. (9.5 mm).

2.3.1.3 Special Paper Types

2.3.1.3.1 Plastic-coated heavyweight or mediumweight roll paper requires additional protection. Increase the demand area by 25% when control mode, density/area sprinklers are used. Increase the number of sprinklers by 25% when control mode, special application sprinklers are used. When suppression mode sprinklers are used with heavyweight paper refer to Table 9.

Plastic-coated infers a thin coating such as that found on a milk carton. Plastic laminate paper consisting of paper and plastic layers which can often be separated, may need plastic protection per Data Sheet 8–9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.

2.3.1.3.2 Treat asphalt laminated paper as plastic-coated heavyweight paper. Asphalt laminated paper is made up of two or more sheets of paper bonded together with one or more layers of asphalt.

2.3.1.3.3 Treat raw paper based roofing felt (without asphalt) as a heavyweight paper. Roofing felt, in this case, is made from porous soft paper made from cotton and wool rags and paper stock.

2.3.1.3.4 Crepe Paper. Crepe paper described in the lightweight paper definition in the appendix of this data sheet refers to the decorative type crepe paper (party streamers) and other similar crepe papers. However, some crepe papers might not be as light or expandable as other crepe papers, and lightweight paper protection might not be justified. Bench testing can help determine the classification.

2.3.1.4 Rack Storage of Rolled Paper

2.3.1.4.1 Protect rack storage of mediumweight and heavyweight roll paper as a Class 3 Commodity. Fires with on-end storage of roll paper behave differently than fires with the rolls stored in racks. Fires with on-end storage produce a continuous, strong fire plume that may result in many sprinklers operating. Protect rack storage of lightweight paper as an Unexpanded Plastic Commodity. These guidelines are for rolls stored on their ends or on their sides. Refer to Data Sheet 8-9 for protection guidelines of Class 3 and Plastic commodities.

2.3.1.5 Axial Rod or Tambour Storage

2.3.1.5.1 Protect heavyweight or mediumweight roll paper on horizontal axial rods as on-end, unbanded, open array, roll paper.

2.3.1.5.2 Limit storage height to 20 ft (6.1 m). If the storage height exceeds 20 ft (6.1 m) provide Approved rack storage in-rack sprinklers at not more than 12 ft (3.7 m) vertical intervals. When only one level of in-rack sprinklers is provided, design for in-rack sprinkler water demand for eight sprinklers flowing a minimum of 30 gpm (115 lpm) each. When two or more levels are provided, in-rack sprinkler water demand should be 14 sprinklers flowing a minimum of 30 gpm (115 lpm) each. When in-rack sprinklers are used design the ceiling demand based on the height of storage above the highest level of in-rack sprinklers.

2.3.1.6 0n-Floor, On-End Storage Using Wood Pallets

2.3.1.6.1 Provide sprinkler protection the same as if the storage did not use pallets. When pallets are used, protect storage based on an open array arrangement.

2.3.1.7 Banding

2.3.1.7.1 Metal bands or steel baling wire applied around the circumference of roll paper reduce unwinding or peeling. Protection requirements are reduced, in many storage arrangements, if rolls are banded with metal or steel. Some roll paper is banded with plastic bands that are black and shiny, hence, easily confused with steel bands. Protect roll paper storage with plastic banding as if it were not banded at all. Plastic bands will melt and drop off if the rolls are involved in a fire.

2.3.1.8 Paper Weight

2.3.1.8.1 Base the paper classification on paper weight in lb/1000 ft^2 (g/m^2) and texture, not the paper trade name. Definitions of paper weight and types of paper can be found in Appendix A, Glossary of Terms. Protect locations having mixed storage or several different storage arrangements for the greatest storage hazard.

2.3.2 Automatic Sprinklers

2.3.2.1 General Guidelines

2.3.2.1.1 Use wet pipe sprinkler systems whenever possible for all types of roll paper storage.

2.3.2.1.2 When wet systems are impractical, use dry pipe or preaction systems to protect lightweight paper stored on-side and heavyweight or mediumweight paper in any storage array. Protect lightweight paper stored on-end with preaction systems when storage in heated areas is not possible.

2.3.2.1.3 Do not use gridded dry pipe and gridded preaction systems. These systems result in delayed water delivery times.

2.3.2.2 Dry Systems

2.3.2.2.1 When dry systems are unavoidable, use systems limited to 500 gal (1890 L) or less capacity with a quick opening device. Systems with more than a 500 gal (1893 L) capacity may be used, if water delivery time to the inspector's test connection is 60 seconds or less, starting at normal air pressure in the system and with the quick opening device in operation.

2.3.2.3 Preaction Systems

2.3.2.3.1 Use FM Approved (see Appendix A for definition) preaction sprinkler systems.

2.3.2.3.2 Maintain preaction systems regularly at proper design, testing and maintenance levels. See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for new installations and Data Sheet 2-81, *Fire Safety Inspections and Sprinkler System Maintenance*, for sprinkler system maintenance and testing of existing locations.

2.3.2.3.3 Locate detectors at the ceiling. When the detectors are spaced the same as the allowable sprinkler spacing, use the wet system water demands to protect the storage. When the detector spacing is greater than the allowable sprinkler spacing, use the dry system water demands.

2.3.2.3.4 Do not space detectors greater than the allowable sprinkler spacing for lightweight paper stored on-end.

2.3.2.3.5 Use only Approved heat-actuated detectors on single-zone circuitry for electrically actuated preaction systems. Use fixed temperature, rate-of-rise, or combination fixed temperature/rate-of-rise type.

2.3.2.3.6 Detectors of preaction systems with other types of activation must conform to the preaction system Approval listing.

2.3.2.4 Pipe Layout

2.3.2.4.1 Protect risers against impact from handling equipment or falling rolls. Feed mains should be given maximum practical protection from external stress.

2.3.2.5 Automatic Sprinkler Categories

FM Global groups automatic sprinklers into three categories. Appendix A defines these categories. The sprinkler protection is listed using the following sprinkler terminology. Refer to Appendix A for additional information.

Control Mode, Density/Area — Design is based on water density over a specified area of coverage. These sprinklers are expected to pre-wet combustibles, cool the ceiling area over the fire, and cool the ceiling area adjacent to the fire to prevent excessive sprinkler openings.

Control Mode, Specific Application — Design is based on a specified number of sprinklers and minimum sprinkler discharge pressure. These sprinklers are expected to pre-wet combustibles, cool the ceiling area over the fire and cool the ceiling area adjacent to the fire to prevent excessive sprinkler openings.

Suppression Mode (early suppression, fast-response [ESFR]) — Design is based on a specified number of sprinklers operating at a minimum sprinkler discharge pressure. The sprinklers directly over the fire are expected to operate early and discharge large amounts of water to suppress the fire.

2.3.2.5.1 When control mode, area/density sprinklers are used, use sprinklers rated at 286°F (141°C).

2.3.2.5.2 Limit the coverage area of control mode, area/density sprinklers with a K-factor of 8.0 or more to a minimum of 70 ft^2 (6.5 m^2) and a maximum of 100 ft^2 (9.3 m^2).

2.3.2.5.3 When control mode, area/density sprinklers with a K-factor of 5.6 are used, use sprinklers nominally rated at 286°F (141°C) and design coverage areas to be between 50 and 100 ft^2 (4.6 and 9.3 m^2). Do not use area/density sprinklers with a K-factor of 5.6 where the required densities are greater than 0.30 gal/min/ft^2 (12 mm/min).

2.3.2.5.4 Control mode, specific application sprinklers may be used for the protection of some roll paper storage arrangements. Follow installation guidelines in Data Sheet 2-0.

2.3.2.5.5 Suppression Mode sprinklers may be used for some roll paper storage arrangements. For the storage arrangements listed, it can be expected that suppression mode sprinklers will provide superior performance to control mode, area/density or specific application sprinklers. Do not use suppression mode sprinklers for storage and building configurations that are not listed in this data sheet. Use only wet pipe systems when suppression mode sprinklers are installed.

2.3.2.6 Automatic Sprinkler Temperature Rating

2.3.2.6.1 Use 286°F (141°C) nominal temperature rated sprinklers for control mode, density/area sprinklers for new installations, except as noted below. There may be locations where 165°F (74°C) rated sprinklers are mandated by authorities having jurisdiction. When 165°F (74°F) rated sprinklers are used in new installations multiply the 286°F (141°C) sprinkler area by 1.7 to obtain the new area. No adjustment is required for 212°F (100°C) rated sprinklers.

2.3.2.6.2 Control mode, density/area sprinklers of 286°F (141°C), 212°F (100°C) and 165°F (74°C) nominal temperature rating are equally acceptable for on-side storage of heavyweight and mediumweight rolled paper, and no adjustment to design area is necessary.

2.3.2.6.3 Control mode, specific application sprinklers may have either a 286°F (141°C) or 165°F (74°C) nominal temperature rating for wet-pipe systems and 286°F (141°C) nominal temperature rating for dry-pipe systems.

2.3.2.6.4 Use 165°F (74°C) nominal temperature rating when suppression mode sprinklers are used.

2.3.2.7 Excessive Clearance

2.3.2.7.1 When clearance between ceiling sprinklers and the top of storage exceeds 10 ft (3.0 m) but is not greater than 20 ft (6.1 m) do either of the following:

a) Increase the demand area by 1000 ft^2 (93 m^2).

b) Provide protection that is adequate for the storage height which would correspond to 10 ft (3.0 m) clearance.

Example: 15 ft (4.6 m) high storage of mediumweight paper in a 30 ft (9.1 m) high building. Increase the demand area by 1000 ft^2 (93 m^2) or protect for 20 ft (6.1 m) high storage in a 30 ft (9.1 m) high building.

2.3.2.7.2 When clearance between ceiling sprinklers and the top of storage exceeds 20 ft (6.1 m) do either of the following:

a) Provide protection that is adequate for the storage height that would correspond to 10 ft (3.0 m) clearance.

Example: 10 ft (3.0 m) high storage of mediumweight paper in a 35 ft (10.7 m) high building. Protect for 25 ft (7.6 m) high storage in a 35 ft (10.7 m) high building.

b) Install a false ceiling and sprinklers over the top of the storage following the recommendations in Section 2.2.2.

2.3.3 Protection of Lightweight Paper

2.3.3.1 Table 2 provides sprinkler densities and design areas for the protection of lightweight paper using control mode, area/density sprinklers.

2.3.3.2 For storage heights within a given range for on-end storage in Table 2, it is acceptable to interpolate between areas of demand. It is not acceptable to interpolate between densities. Do not interpolate between sprinkler clearances in Table 2.

2.3.3.3 Storage locations with lightweight roll paper stacked on-end, in a closed or open array or banded/unbanded standard array can be protected using control mode, specific application sprinklers. Table 3 provides recommendations using sprinklers with K-factors of 11.2(16.1) and 14.0(20.2) gpm/$(psi)^{½}$ (lpm/$(kPa)^{1/2}$). Do not interpolate between the number of sprinklers in Table 3.

Table 2. Protection for Lightweight Roll Paper Using Control Mode, Density/Area Sprinklers (see Notes 1, 2, 3, 4 and 5)

Array	Storage Height ft (m)	Control Mode, Density Area Sprinklers				
		Density gpm/ft^2 mm/min	Sprinkler Clearance over Storage, ft (m)			
			3 to 5 (0.9 to 1.5)	> 5 to 10 (1.5 to 3.0)	> 10 to 15 (3.0 to 4.6)	> 15 to 20 (4.6 to 6.1)
			Area ft^2(m^2)	Area ft^2(m^2)	Area ft^2(m^2)	Area ft^2(m^2)
On-End (see Note 4)	< 12 (3.7)	0.30(12)	4000(380)		5000(465)	6000 (560)
	12 to 15 (3.7 to 4.6)	0.60(24)	2500-3000 (230-280)	3000-3500 (280-325)	3500-4000 (325-370)	NA
	15 to 20 (4.6 to 6)	0.60 (24)	3000-4000 (280-370)	3500-6000 (325-560)	NA (see Note 4)	NA (see Note 4)
		0.80 (33)	2500 (230)	NA (see Note 4)		
On-Side	Below 12 (3.7)	0.20 (8)	6000 (555) *10,000 (930)	Density and demand areas given for on-side storage are adequate for maximum building height of 25 ft (7.6 m)		
	12 to 15 (3.7 to 4.6)	0.25 (10)	6000 (555) *9000 (835)			
	> 15 (3.7) to 20 (6)	0.35 (14)	5000 (465) *6500 (605)			

Note 1: An asterisk (*) indicates dry system demand areas.
Note 2: For storage heights within a given range, it is acceptable to interpolate between demand areas. For clearances within the given ranges, it is not acceptable to interpolate, i.e., 20 ft (6.1 m) high on-end storage requires the same protection whether there is 8 ft (2.4 m) clearance or 10 ft (3 m) clearance.
Note 3: Use only wet pipe systems or preaction systems with detector spacing no greater than the allowable sprinkler spacing for lightweight roll paper stored on-end.
Note 4: NA (not acceptable). Reduce storage height or provide false ceiling over the storage with sprinklers below the ceiling. Adjust sprinkler operating areas for the clearance between the top storage and the false ceiling.
Note 5: Acceptable arrangements for on-end storage are open, standard or closed. Paper can be banded or unbanded.

Table 3. Lightweight Roll Paper Storage Protection, Control Mode Specific Application

Maximum Storage Height, ft (m)	Maximum Building Height, ft (m)	K-factor, gpm/(psi)^{½}, (lpm/(kPa)^{½})	Number of Sprinklers @ Pressure lb/in^2 (bar), Temperature Rating °F (°C)
20 ft (6.1)	30 ft (9.1)	11.2 (16.1) (Note 1)	25 @ 75 (5.1), 165 (74) or 286 (144)
20 ft (6.1)	30 ft (9.1)	16.8 (24.2) (Note 1)	25 @ 34 (2.3), 165 (74) or 286 (144)
25 ft (7.6)	30 ft (9.1)	14.0 (20.1) (Note 2)	16 @ 75 (5.1), 165 (74)
25 ft (7.6)	40 ft (12.2)	14.0 (20.1) (Note 2)	25 @ 75 (5.1), 165 (74)

Note 1. Design and install the sprinkler system using the recommendations in Data Sheet 2-0.
Note 2. Use Approved suppression mode sprinkler only for this control mode specific application. Suppression mode sprinklers are listed in the *Approval Guide* in the section titled AUTOMATIC SPRINKLERS, Suppression Mode, Nominal Discharge Coefficient of 14.0 gpm/(psi)^{½} (20.2 lpm/(kPa)^{½}). Design and install sprinkler system using the recommendations in Data Sheet 2-0.
Note 3. Acceptable storage arrangements are on-side or on-end. Paper can be banded or unbanded. Acceptable arrays are open, standard or closed.

2.3.4 Protection of Mediumweight Paper

2.3.4.1 Tables 4, 5 and 6 provide sprinkler protection criteria for the protection of mediumweight paper using control mode, density/area and specific application sprinklers and suppression mode sprinklers respectively.

2.3.4.2 For storage heights in Table 4 that are less than the maximum, a direct linear interpolation may be made between the density and area for that maximum storage height and the density and area for the next lowest maximum storage height.

2.3.5 Protection of Heavyweight Paper

2.3.5.1 Tables 7, 8 and 9 provide sprinkler protection criteria for the protection of heavyweight paper using control mode, density/area and specific application sprinklers and suppression mode sprinklers respectively.

2.3.5.2 For storage heights in Table 7 that are less than the maximum, a direct linear interpolation may be made between the density and area for that maximum storage height and the density and area for the next lowest maximum storage height.

Table 4. Mediumweight Roll Paper Storage Protection, Control Mode, Density/Area Sprinkler (Density/Area, gpm/min/ft²/ft² [mm/min/m²])

Maximum Storage Height ft (m) (see Note 3)	System Type	Storage Arrangement (see Notes 1, 2 and 4)				
		Rolls On-end			Rolls On-side	
		Open or Standard Array		Closed Array	Nested	With Dunnage
		Not Banded	Banded			
10 (3)	Wet	0.30/2000 (12/186)			0.15/6000 (6/560)	
	Dry	0.30/4500 (12/418)				
15 (4.6)	Wet	0.45/3000 (18/279)	0.45/2500 (18/232)	0.30/2000 (12/186)		
	Dry	0.45/4500 (18/418)	0.45/4000 (18/372)	0.30/4500 (12/418)		
20 (6.1)	Wet	0.60/3500 (24/325)	0.60/2500 (24/232)	0.45/2500 (18/232)	0.20/4500 (8/420)	
	Dry	0.60/4000 (24/372)	0.60/3500 (24/325)	0.45/4000 (18/372)		
25 (7.5)	Wet	0.60/4000 (24/372)	0.60/3500 (24/325)	0.60/2500 (24/232)	0.20/5200 (8/483)	0.20/5700 (8/530)
	Dry	0.60/4500 (24/418)	0.60/4000 (24/372)	0.60/3500 (24/325)		
30 (9.1)	Wet	0.60/4500 (24/418)	0.60/4000 (24/372)	0.60/3000 (24/279)	0.20/6000 (8/560)	0.20/7000 (8/650)
	Dry	0.60/5000 (24/464)	0.60/4500 (24/418)	0.60/4000 (24/372)		

Note 1: When clearance is 3 to 5 ft (0.9 to 1.5 m), reduce the demand areas by 500 ft² (46 m²), but final demand area should not be less than 2000 ft² (186 m²) for wet systems or 2600 ft² (242 m²) for dry systems.

Note 2: When clearance exceeds 10 ft (3 m), see Section 2.3.2.7, Excessive Clearance.

Note 3: For storage heights that are less than the maximum, a direct linear interpolation may be made between the density and area for that maximum storage height and the density and area for the next lowest maximum storage height.

Note 4: For 5 ft (1.5 m) high on-side storage of mediumweight paper, nested or with dunnage, the demand area can be reduced to 2500 ft² (232 m²).

Table 5. Mediumweight Roll Paper Storage Protection, Control mode, Specific Application Sprinkler (Number of Sprinklers at Pressure, lb/in² [bar])

Maximum Storage Height, ft (m)	Maximum Building Height, ft (m)	Wet-Pipe System		Dry Pipe System	
		K-factor 11.2, 165°F (64°C) or 286°F (141°C)	K-factor 16.8, 165°F (64°C)	K-factor 11.2, 165°F (64°C) or 286°F (141°C)	K-factor 16.8, 165°F (64°C)
20 (6.1)	30 (9.1)	15 @ 50 (3.4)	15 @ 22 (1.5)	25 @ 50 (3.4)	25 @ 22 (1.5)

Note 1. Acceptable arrangements for on-end storage are standard or closed arrays. Paper can be banded or unbanded.

Table 6a. Mediumweight Roll Paper Storage Protection, Suppression Mode Sprinkler, Pendent (Number of Sprinklers at Pressure, lb/in² [bar])

Storage Height, ft (m)	Building Height, ft (m)	K-factor 14.0, 165°F (74°C)	K-factor 16.8, 165°F (74°C)	K-factor 25.2, 165°F (74°C)
20(6.1)	30(9.1)	12 @ 50 (3.4)	12 @ 35 (2.4)	12 @ 20 (1.4)
	35 (10.7)	12 @ 75 (5.1)	12 @ 52 (3.6)	12 @ 30 (2.1)
	40(12.2)	12 @ 75 (5.1)	12 @ 52 (3.6)	12 @ 40 (2.7)

Note 1. Acceptable arrangements for on-end storage are standard or closed arrays. Paper can be banded or unbanded.

Table 6b. Mediumweight Roll Paper Storage Protection, Suppression Mode Sprinkler, Upright
(Number of Sprinklers at Pressure, lb/in^2 [bar])

Storage Height, ft (m)	*Building Height, ft (m)*	*K-factor 14.0, 165°F (74°C)*	*K-factor 16.8, 165°F (74°C)*
20 (6.1)	30 (9.1)	12 @ 50 (3.4)	12 @ 35 (2.4)
	35 (10.7)	12 @ 75 (5.1)	12 @ 50 (3.4)

Note 1. Acceptable arrangements for on-end storage are standard or closed arrays. Paper can be banded or unbanded.

Table 7. Heavyweight Roll Paper Storage Protection, Control Mode, Density/Area Sprinkler
(Density/Area, gpm/min/ft^2/ft^2 [mm/min/m^2])

Storage Height ft (m)	*System Type*	*Storage Arrangement (see Notes)*						
		Rolls On-end					*Rolls On-side*	
		Open Array		*Standard Array*		*Closed Array*	*Nested*	*With Dunnage*
		Not Banded	*Banded*	*Not Banded*	*Banded*			
10 (3)	Wet	0.30/2000 (12/185)				0.30/2000 (12/185)	0.15/6000 (6/560)	
	Dry	0.30/4500 (12/420)						
15 (4.6)	Wet	0.30/3500 (12/325)	0.30/3000 (12/280)	0.30/2000 (12/185)	0.30/2000 (12/185)			
	Dry	0.30/6000 (12/560)	0.30/6000 (12/560)	0.30/4500 (12/420)	0.30/4500 (12/420)			
20 (6.1)	Wet	0.45/4000 (18/370)	0.45/3500 (18/325)	0.45/2000 (18/185) **Note 5**	0.30/2500 (12/230)		0.20/4500 (8/420)	
	Dry	0.45/5000 (18/465)	0.45/5000 (18/465)	0.45/4500 (18/420) **Note 5**	0.30/5000 (12/465)			
25 (7.6)	Wet	0.60/3500 (24/325)	0.60/3000 (24/280)	0.45/4000 (18/370)	0.45/3500 (18/325)	0.45/3000 (18/280)	0.20/5200 (8/480)	0.20/5700 (8/530)
	Dry	0.60/4500 (24/420)	0.60/4000 (24/370)	0.60/3500 (24/325)	0.45/5000 (18/465)			
30 (9.1)	Wet	0.60/4500 (24/420)	0.60/4000 (24/370)	0.60/3000 (24/280)	0.60/3000 (24/280)	0.60/2500 (24/230)	0.20/6000 (8/560)	0.20/7000 (8/650)
	Dry	0.60/5000 (24/465)	0.60/4500 (24/420)	0.60/4000 (24/370)	0.60/4000 (24/370)			

Note 1: When clearance is 3 to 5 ft (0.9 to 1.5 m), reduce the demand areas by 500 ft^2 (46 m^2), but final demand area should not be less than 2000 ft^2 (186 m^2) for wet systems or 2600 ft^2 (242 m^2) for dry systems.

Note 2: When clearance exceeds 10 ft (3 m), see Section 2.3.2.7, Excessive Clearance.

Note 3: For storage heights that are less than the maximum, a direct linear interpolation may be made between the density and area for that maximum storage height and the density and area for the next lowest maximum storage height.

Note 4: For 5 ft (1.5 m) high on-side storage of heavyweight paper, nested or with dunnage, the demand area can be reduced to 2500 ft^2 (232 m^2).

Note 5: This note pertains to standard array, unbanded storage at 20 ft (6.1m). For existing installations, adequate protection will be provided with 0.3 gpm/ft^2 (12 mm/min) over 3000 ft^2 (280 m^2) for a wet system or 0.3 gpm/ft^2 (12 mm/min) over 5500 ft^2 (510 m^2) for a dry system.

Table 8. Heavyweight Roll Paper Storage Protection, Control Mode, Specific Application Sprinkler
(Number of Sprinklers at Pressure, lb/in^2 [bar])

Maximum Storage Height, ft (m) (see Note)	*Maximum Building Height, ft (m)*	*Wet-Pipe System*		*Dry Pipe System*	
		K-factor 11.2 (160), 165°F (64°C) or 286°F (141°C)	*K-factor 16.8 (240), 165°F (64°C)*	*K-factor 11.2 (160), 286°F (141°C)*	*K-factor 16.8 (240), 286°F (141°C)*
26 (7.9)	60 (18.3)	15 @ 50 (3.4)	15 @ 22 (1.5)	25 @ 50 (3.4)	25 @ 22 (1.5)

Note 1: Acceptable arrangements for on-end storage are standard or closed array. On-end storage in an open array arrangement is not acceptable.

Table 9a. Heavyweight Roll Paper Storage Protection, Suppression Mode Sprinkler, Pendent (Number of Sprinklers at Pressure, lb/in^2 [bar])

Paper Type	*Storage Height, ft (m)*	*Building Height, ft (m)*	*K-factor 14.0 (200), 165°F (74°C)*	*K-factor 16.8 (240), 165°F (74°C)*	*K-factor 25.2 (360), 165°F (74°C)*
Heavyweight	25 (7.6)	30 (9.1)	12 @ 50 (3.4)	12 @ 35 (2.4)	12 @ 20 (1.4)
	30 (9.1)	40 (12.2)	12 @ 75 (5.1)	12 @ 52 (3.6)	12 @ 40 (2.7
	42 (12.8)	60 (18.3)	-	20 @ 50 (3.4)	-
Plastic Coated Heavyweight	20 (6.1)	30 (9.1)	12 @ 50 (3.4)	12 @ 35 (2.4)	12 @ 20 (1.4)
		40 (12.2)	12 @ 75 (5.1)	12 @ 52 (3.6)	12 @ 40 (2.7)

Note 1: Acceptable arrangements for on-end storage are standard or closed arrays or banded open array when suppression mode sprinklers require a 12 sprinkler design.
Note 2: Acceptable arrangements for on-end storage are standard or closed arrays when suppression mode sprinklers require a 20 sprinkler design.

Table 9b. Heavyweight Roll Paper Storage Protection, Suppression Mode Sprinkler, Upright (Number of Sprinklers at Pressure, lb/in^2 [bar])

Paper Type	*Storage Height, ft (m)*	*Building Height, ft (m)*	*K-factor 14.0, 165°F (74°C)*	*K-factor 16.8, 165°F (74°C)*
Heavyweight	25 (7.6)	30 (9.1)	12 @ 50 (3.4)	12 @ 35 (2.4)
	30 (9.1)	35 (10.7)	12 @ 75 (5.1)	12 @ 50 (3.4)
Plastic Coated Heavyweight	20 (6.1)	30 (9.1)	12 @ 50 (3.4)	12 @ 35 (2.4)
		35 (10.7)	12 @ 75 (5.1)	12 @ 50 (3.4)

Note 1: Acceptable arrangements for on-end storage are standard or closed arrays or banded open array.

2.3.6 Small Hose Connections

2.3.6.1 Provide permanent small hose lines, 1-½ in. (38 mm) not exceeding 100 ft (30.0 m) in length, capable of reaching all roll paper storage areas. Supply small hose by any of the following:

a) A separate piping system for small hose stations.

b) Valved hose connections on sprinkler risers, provided such connections are made upstream from all sprinkler control valves.

c) Adjacent sprinkler systems

2.3.6.2 When small hose stations are supplied from the overhead sprinkler system, and the overhead sprinkler system and small hose are protecting the same area, add 100 gpm (379 lpm) to the sprinkler system hydraulic calculations at the point of the small hose/sprinkler system piping connection.

2.3.7 Hose Demand

2.3.7.1 Allow at least 500 gpm (1890 lpm) for hose stream demand when control mode sprinklers are used or when suppression mode sprinklers require a 20 sprinkler design. Allow at least 250 gpm (945 lpm) for hose stream demand when suppression mode sprinklers are used. Add the hose stream allowances to the sprinkler demand at the point of connection.

2.3.8 Duration of Water Supplies

2.3.8.1 For protection using control mode sprinklers (density/area or specific application), design the combined sprinkler system and hose stream demand to provide a minimum water supply duration of 2 hours.

2.3.8.2 For protection using suppression mode sprinklers with a 12 sprinkler design, design the combined sprinkler system and hose stream demand to provide a minimum water supply duration of 1 hour. For protection using suppression mode sprinklers with a 20 sprinkler design, design the combined sprinkler system and hose stream demand to provide a minimum water supply duration of 2 hours.

2.3.9 Outdoor Storage of Roll Paper

2.3.9.1 Recommended Safe Practices

2.3.9.1.1 The following provides general guidelines for outdoor storage of roll paper. Refer to Data Sheet 1-20, *Protection Against Exterior Fire Exposure* for specific recommendations for protecting exposed buildings from outdoor roll paper storage.

2.3.9.1.2 Limit piles to approximately 200 tons (180 metric tons). Assuming paper weighs 50 lb/ft^3 (800 kg/m^3), a 200 ton (180 metric ton) pile could measure 10 ft high by 20 ft wide by 40 ft long (3.1 m by 6.1 m by 12.2 m). Separate each pile from adjoining piles and public ways by clear spaces of at least 50 ft (15 m).

2.3.9.1.2.1 The following example shows how to determine separation distances using the recommendations in Data Sheet 1-20.

Example: Newsprint stored 8 ft high by 10 ft wide by 100 ft long (2.4 m by 6.0 m by 30 m). Pile separation distances are 50 ft (15 m). The newsprint is stored parallel to a wood walled sprinklered warehouse.

Solution: Treat storage of roll paper as a high hazard exposure based on recommendations in Data Sheet 1-20.

Is $L \leq 24\ H$? yes.

Use equation 1. $S = 3.07 \sqrt{(LH)}$

$S = 3.07 \times 28.3 = 87$ ft (26.5 m)

2.3.9.1.3 Store rolls on-side instead of on-end whenever possible. Peeling or unwinding of the rolls is greatly reduced, which in turn reduces fire intensity.

2.3.9.1.4 Limit pile heights to 20 ft (6 m).

2.3.9.1.5 Prohibit smoking and eliminate other ignition sources from the vicinity of storage areas. This includes any vehicles not being used for roll handling. Install spark-arresting devices on stack incinerators and other spark-producing devices.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

During the 15 year period from 1987–2002, 388 roll paper losses were reported to FM Global. Table 10 gives a breakdown of the losses by peril. Table 11 gives a breakdown of the fire losses by cause.

Table 10. Rolled Paper Storage Losses by Peril

Peril	*Number of Losses*	*Percent of Total Losses*	*Percent of Total (US) Dollars Lost*
Fire	89	22.9	63.0
Sprinkler Leakage	96	24.7	9.6
Wind	28	7.2	7.0
Collapse	20	5.3	7.4
Flood	16	4.1	3.7
Water-Liquid Damage	118	30.4	7.8
Other	21	5.4	1.5
Total	388	100	100

Table 11. Rolled Paper Storage Fires by Cause

Cause	*Number of Losses*	*Percent of Total Losses*	*Percent of Total (US) Dollars Lost*
Exposure	5	5.6	30.4
Incendiary	18	20.2	5.2
Hot Work	3	3.4	5.1
Electrical	13	14.6	11.1
Hot Surface or Friction	8	9.0	4.5
Sparks	4	4.5	1.8
Spontaneous Ignition	4	4.5	1.1
Smoking	5	5.6	2.5
Unknown or No Data	29	32.6	38.3
Total	89	100	100

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-20, *Protection Against Exterior Fire Exposure*.

Data Sheet 1-24, *Protection Against Liquid Damage*.

Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers* .

Data Sheet 2-81, *Fire Safety Inspections and Sprinkler System Maintenance*.

Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*.

Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.

Data Sheet 8-22, *Storage of Baled Waste Paper*.

4.2 NFPA Standards

NFPA 13, *Installation of Sprinkler Systems*.

NFPA 230, *Standard for the Fire Protection of Storage*.

APPENDIX A GLOSSARY OF TERMS

Approved: references to ‘‘Approved’’ in this data sheet means the product and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide* for a complete listing of products and services that are FM Approved.

Standard array: a storage arrangement where uniform diameter rolls on-end, are in stacks butted in one direction and 4 in. (100 mm) or more apart in the other direction. The standard array is the most commonly used array for roll paper storage. The standard array is generally found where rolls are uniform in diameter and clamp trucks are used for storage.

Open array: a storage arrangement where rolls, on-end, are in stacks separated in both directions. Stack separation is 4 in. (100 mm) or more. Open array storage is generally found where rolls are not uniform in diameter.

Closed array: a storage arrangement where uniform diameter rolls, on-end, are in piles of at least four stacks in both directions with stack spacing closer than 4 in. (100 mm). Closed array is rarely found and usually involves stacking by crane.

Banded paper: roll paper that is provided with one or more circumferential steel straps or wires to prevent unwinding.

Plain wrapped paper: roll paper that is provided with a heavyweight wrapper covering the sides and both ends of the roll.

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

Heavyweight paper: all paper that weighs 20 lb/1000 ft^2 (98 g/m^2) or greater. Examples of paper within this class may include (but are not limited to) liner board, corrugating medium, Bristol board, vellum Bristol board, index, cup board, tag, rolled pulp, folding box board and kraft roll wrappers.

Mediumweight paper: all paper with a hard, smooth or glossy finish that weighs less than 20 lb/1000 ft^2 (98 g/m^2) but not less than 10 lb/1000 ft^2 (49 g/m^2). Examples of mediumweight paper may include, but are not limited to, newsprint, tablet, computer, envelope, book, butcher, label, bond, magazine, vellum and bag paper.

Lightweight paper: all paper with an absorbent, fibrous or gauzy texture regardless of weight. Examples may include, but are not limited to, toilet tissue, napkin, crepe, facial tissue and paper towel. Also included in the lightweight paper classification is all paper with a hard, smooth or glossy finish that weighs less than 10 lb/1000 ft^2 (49 g/m^2). Examples of this grade of paper may include (but are not limited to) onion skin, catalog paper, fruit wrap, carbonizing paper and cigarette paper. Some newsprint may weigh as little as 8.6 lb/1000 ft^2 (42 g/m^2).

Storage height: maximum height of storage measured from the floor to the top-most level of storage. For new or proposed buildings or structures, storage height is the maximum distance above the floor that roll paper can be stored considering the size of the rolls, limitations of mechanical handling equipment, and a minimum 3 ft (9 m) clearance between the top of storage and ceiling sprinkler deflectors.

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.

Control Mode, Density/Area: Design is based on water density over a specified area of coverage. These sprinklers are expected to pre-wet combustibles, cool the ceiling area over the fire, and cool the ceiling area adjacent to the fire to prevent excessive sprinkler openings. The nominal discharge coefficient (K-factor) of control mode density/area sprinklers could be 5.6, 8.0, 11.2 or 14.0 gal/min/$(psi)^{1/2}$.

Control Mode, Specific Application: Design is based on a specified number of sprinklers and minimum water supply pressure. These sprinklers are expected to pre-wet combustibles, cool the ceiling area over the fire and cool the ceiling area adjacent to the fire to prevent excessive sprinkler openings. The nominal discharge coefficient (K-factor) of control mode, specific application sprinklers could be 11.2 or 16.8 gal/min/$(psi)^{1/2}$

Suppression Mode: Design is based on a specified number of sprinklers operating at a specific minimum water supply pressure. The sprinklers directly over the fire are expected to operate early. The suppression mode sprinklers are designed to discharge large amounts of water and suppress the fire. The nominal discharge coefficient (K-factor) of suppression mode sprinklers could be 14.0 or 25.2 gal/min/$(psi)^{1/2}$.

APPENDIX B DOCUMENT REVISION HISTORY

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 2.6.5. 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.

APPENDIX C FIRE BEHAVIOR

C.1 General

Destruction of several fully sprinklered roll paper warehouses, and loss of many tons of roll paper in yard storage have demonstrated that roll paper storage presents a serious fire hazard. The hazards are aggravated by material handling methods and economic pressures that lead to increased storage heights and reduced aisle space.

If roll paper storage is inadequately protected, fire development and spread is unusually severe and rapid. Exposed building steel can quickly heat to temperatures at which it fails structurally. Excessive steel deflection can break sprinkler piping and deprive the building contents of fire protection at a time of maximum need. Wind and total absence of sprinkler protection make yard fires especially difficult to control.

Fire spreading up the side of a paper column quickly burns through the outer ply. Unless there is some arrangement to prevent it, paper then unwinds or peels from the rolls. Peeled material rapidly increases burning surfaces and spreads fire by contact with adjacent piles. Rolls continually shed outer layers wet by sprinkler discharge, exposing dry paper.

C.2 Paper Grades

Fire tests and loss experiences have shown that the weight or grade of paper can affect fire severity. Fires involving lightweight papers operate more sprinklers, create higher temperatures and cause significantly more damage than do fires involving heavyweight paper.

Mediumweight papers can exhibit more rapid flame spread than heavyweight paper, but the fire hazard is not quite as severe as with lightweight paper.

The paper industry measures paper in pounds per 1000 ft^2, 2600 ft^2, 3000 ft^2 or per total area of a ream of paper (usually 500 sheets) or in g/m^2. It should be verified as to which of the methods is used when classifying the paper at any location. For purposes of this data sheet, all basis weights are given in lb/1000 ft^2 (g/m^2).

Table 12 shows the base areas in ft^2 for the various kinds of paper that are typically used in the paper industry. For example, given the weights shown on labels of roll paper stock in a printing plant, this is the weight of 500 sheets with dimensions of 17 $\times$ 22 in. (430 $\times$ 560 mm), which is a total area of 1298.6 ft^2 (120.7 m^2). To convert this to a 1000 ft^2 (92.9 m^2) basis:

X = the basis weight in lb shown on the label

Y = 1298.6 ft^2, which is the area for the basis weight shown on the label used by that particular industry from Table 12

basis weight (lb/1000 ft^2) = (X/Y) $\times$ 1000

if X = 21 lb on the label, then:

basis weight (lb/1000 ft^2) = (21/1298.6) × (1000) = 16 lb/1000 ft^2 (78 g/m^2)

C.3 On-End Storage

On-end storage is more varied and more widely used than on-side storage. Roll paper is usually handled by using clamp or vacuum-clamp lift trucks or overhead cranes. Use of this equipment usually causes variation in vertical flue spaces.

Where clamp-jaw equipment is used, jaw clearance space of at least 4 in. (100 mm) is usual, resulting in an open or standard array storage arrangement. Rolls varying in diameter provide spaces between stacks that may reach several feet. Fire can grow rapidly in such storage; not only can paper peel freely, but air supply is favorable for burning in flue-like spaces. In addition, heat radiated and re-radiated from one stack to another promotes intense fires.

Individual stacks consisting of rolls with assorted diameters, such as butt rolls, are considered an open array.

When all rolls in a sector of storage are of the same diameter, adjacent stacks can be placed in or nearly in contact in both directions. Close stacking or butting requires extra care and effort by equipment operators and their supervisors, particularly where clamp-jaw equipment is used. Less effort is needed where vacuum-clamp equipment is used, but some papers cannot be handled by suction. In addition to space economy, this closed array storage arrangement has important fire protection advantages. Unwinding or peeling is limited and air supply is restricted. If there is less than a 4 in. (100 mm) separation between stacks, fire growth is slow and intensity is relatively low. Standard array storage also can reduce fire intensity in heavyweight paper, but not quite as effectively as closed array.

Metal bands greatly reduce unwinding or peeling; such bands may be those used to protect roll ends during shipment or those with slide fasteners. Steel baling wire applied tightly by hand also is effective. Some roll paper is banded with plastic bands that are black and shiny, hence, easily confused with steel bands. Since plastic bands are expected to melt and drop off under fire condition, roll paper storage with plastic banding should be protected as if it were not banded at all.

Some lightweight and mediumweight roll paper is wrapped with a heavier grade of paper for protection during shipment and storage. The wrapper tends to reduce the fire hazard of the lighter grade paper. During the early stages of a fire, the paper being stored generally takes on the fire development characteristics of the wrapper.

Table 12. Trade or Basic Paper Size

Kind of paper	*Trade or basic size*	*Trade size area, ft^2*
Paperboard	1000 ft^2	1000.0
Writing and Printing	17×22–500	1298.6
Blotting	19×24–500	1583.3
Cover	20×26–500	1805.6
Carbon paper	20×30–500	2083.3
Cardboard	22×28–500	2138.9
Bristol and tag	22-½×28-½–500	2226.6
Binder's board	25-¼×30-¼–500	2652.1
Index	25-½×30-½–500	2700.5
News, wrapping, tissue, paperboard, bag paper	24×36–500	3000.0
Tissue	24×36–480	2880.0
Book	25×38–500	3298.6
Newsboard	26×38–500	3430.6
Former TAPPI standard size	25×40–500	3472.2
CONVERSION FACTORS: To convert ft^2 to m^2, multiply by 0.093 To convert lb to kilograms (kg), multiply by 0.4536 To convert lb/1000ft^2 to g/m^2 multiply by 4.88		

Rolls are sometimes stored vertically on pallets; the fire hazards are essentially the same as storage without pallets.

C.4 On-Side Storage

On-side storage arrangements prevent unwinding or peeling. 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 fire is well shielded from fire fighting efforts, can involve a large portion of the storage, and can become quite severe in vertical flues between roll ends.

C.5 Storage on Axial Rods

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