Advances in Sprinkler Technology
Data Sheets 2-0 and 8-9

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Agenda

- Sprinkler Protection History – Then and Now
- Movement Towards Sprinkler Categories based on Occupancy Hazard
- Movement Towards a Single Sprinkler System Design Format
- Data Sheet 2-0 Installation Guidelines for Automatic Sprinklers
- Data Sheet 8-9 Design Guidelines for Storage Facilities
- Retroactivity of Data Sheets 2-0 and 8-9

What is FM Global?

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What is FM Global?

- FM Global’s market share includes:
  - 45% of the Fortune 100 Companies
  - 42% of the Fortune 500 Companies
- FM Global is a recognized industry leader in property insurance
- FM Global has been recognized as:
  - Best Global Property Insurer
  - Best Global Property Insurer – North

Majority of Losses are Preventable

- Research
- FM Approved Products
- Engineering

Practical and Proven Global Loss Prevention Engineering Solutions

Investment in Engineering & Research

- World’s largest full-scale fire test lab and research campus
- Dedicated to the study of loss prevention
Research Campus

Full Scale Fire Tests

- Two moveable ceilings up to 60 ft (18.3 m)
- Test storage arrays from 5 ft (1.5 m) to 55 ft (16.8 m)
- Visitors Days for Campus tours

FM Approvals

Confidence that a product installed in your facility will perform as intended!
Reducing your Risks
What are FM Global Data Sheets?

- Offer best advice on how to minimize property damage and business interruption
- Written by the Engineering Standards division
- Supported by the Research division
- Used to evaluate loss potentials at our client locations
- Recommendations offered when hazards encountered are not protected in accordance with appropriate data sheet

What Does FM Global Do for the Fire Protection Community?

Innovate

Example of Full Scale Fire Testing

Evaluating an existing European Code for rack storage w/IRAS back in 1990's
- Protection of rack storage with longitudinal flue space in-rack sprinklers only
- 55 ft (16.5 m) rack storage
- 60 ft (18 m) ceiling height
- Cartoned unexpanded plastic
- Standard response in-rack sprinklers
Pipe Schedule

- Pipe schedule was categorized based on occupancy hazard as either:
  - Light Hazard
  - Ordinary Hazard
  - Extra Hazard

Pipe Schedule

- Sizing requirements for an ordinary hazard pipe schedule sprinkler system:

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter</th>
<th>Maximum Number of Sprinklers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1-1/4</td>
<td>3</td>
</tr>
<tr>
<td>1-1/2</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
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<td>2-1/2</td>
<td>20</td>
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<td>3</td>
<td>40</td>
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<td>4</td>
<td>100</td>
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<tr>
<td>6</td>
<td>180</td>
</tr>
<tr>
<td>8</td>
<td>270</td>
</tr>
</tbody>
</table>
Change in Industrial Practices
Circa 1940 - 1950:
– Steel construction for buildings (collapse)
– Invention of forklift truck and storage racks constructed of steel (higher storage)
– Change from wood, metal and glass materials to plastic materials (much higher heat release fires)

Warehouse Fires With Pipe Schedule Sprinkler Systems

Innovations by FM Global – 1950s
Standard Spray Sprinkler
K 5.6 (K 80)
**Density**

- What is density?
  - Sprinkler flow ÷ sprinkler area of coverage
  - Establishes minimum rate of water discharge needed

**How is Density Used?**

- Converted into minimum flow and pressure at sprinkler

\[ Q = D \times S \times L \]
\[ P = \left(\frac{Q}{K}\right)^2 \]

- \( Q \): Sprinkler flow in gpm (Lpm)
- \( P \): Sprinkler pressure in psi (bar)
- \( D \): Density in gpm/ft² (mm/min)
- \( S \): Spacing of sprinklers on branchlines ft (m)
- \( L \): Spacing of sprinklers between branchlines ft (m)
- \( K \): K-factor (size of sprinkler opening) in gmp/psf⁰.⁵ (Lpm/bar⁰.⁵)
Density and Sprinkler Spacing

- Sprinkler spacing affects minimum flow and pressure at sprinkler
  - \( Q = D \times S \times L \), gpm (Lpm)
  - \( P = \left( \frac{D \times S \times L}{K} \right)^2 \), psi (bar)

Reducing sprinkler spacing in design can reduce design flow and pressure

Demand Area

- Area at ceiling in which all sprinklers expected to operate during fire
- Use demand area to:
  - determine No. of sprinklers expected to operate during fire
  - determine No. of sprinklers operating on each branchline

Total No. of AS = Demand Area / (S x L)

No. of AS per branchline = \([SF \times (Demand \ Area)^{0.5}] / S\)

SF = Shape Factor (elongation value driven by ceiling slope)

Density/Demand Area Design

- Flow rate per sprinkler for all sprinklers in design area
- Allowance for hose streams
- Water supplies for sprinklers and hoses at minimum duration
1950's/1960's Sprinkler Technology

- 20 ft (6.0 m) Storage
- 30 ft (9.0 m) Ceiling
- Class 4 Commodity
- Open-Frame Double-Row Rack
- 8 ft (2.4 m) Wide Aisle
- K5.6 (K80) Upright Ceiling Sprinkler
- Standard-Response
- 5 ft x 10 ft Spacing
- 0.6 gpm/ft² (24 mm/min)

Then came...

- A bunch of Control Mode Density Area (CMDA) sprinklers...
  - Large Orifice (17/32") Sprinkler
  - Extra Large Orifice (ELO) Sprinkler
  - Very Extra Large Orifice (VELO) Sprinkler
  - Really Ginormous Orifice (RGO) Sprinkler

Installation guidelines for these sprinklers evolved into DS 2-8N.
FM Global Innovations – 1970’s

- Larger water droplets for penetration through fire plume
- Better protection of storage arrangements

Which lead to...

The K11.2 (K160) “Large-Drop” Sprinkler, the first Control Mode Specific Application (CMSA) sprinkler

Which lead to...

More CMSA Sprinklers, including the:
- K16.8 (K240)
- K19.6 (K280)
- K25.2 (K360) and
- K25.2EC (K360EC)
Then came...

New sprinkler design format - Number of sprinklers at minimum pressure

Installation guidelines for these sprinklers evolved into DS 2-7

FM Global Innovations – 1970’s

• “Residential” sprinkler concept
• Quick-response thermal element

FM Global Innovations – 1980’s

• Fire Suppression by the Actual Delivered Density Concept
ADD Concept

- Amount of water
- Time
- RDD
- ADD
- Suppression achieved in this zone

FM Global Innovations – 1980’s

- Fire Suppression by the Actual Delivered Density Concept
- Modifying sprinkler deflector design for pendent sprinklers

Example of ADD and deflector design

- Spray Sprinkler Head
Example of ADD Testing and Deflectors

Then came...
• A bunch of Suppression Mode (SM) sprinklers
  – K14 (K200) upright, K16.8 (K240) upright, K14.0 (K200) pendent, K16.8 (K240) pendent, K22.4 (K320) pendent, & K25.2 (K360) pendent

Installation standard for these sprinklers was DS 2-2

FM Global Innovations – 1980’s
• Fire Suppression by the Actual Delivered Density Concept
• Modifying sprinkler deflector design for pendent sprinklers
• Obstruction guidelines for sprinklers over storage
Suppression Mode Sprinkler Installation Guidelines

Advances in Sprinkler Technology

- Orifice size increasing
- Quicker response time
- Deflector design evolved

Reasons for Innovations in 2010

- Three different sprinkler categories
  - Control Mode Density Area (CMDA)
  - Control Mode Specific Application (CMSA)
  - Suppression Mode
Reasons for Innovations in 2010

• Three different sprinkler categories
• Terminology that implies performance
  – Control Performance
  – Suppression Performance

• Three sets of installation guidelines
Movement Towards Sprinkler Categories Based on Occupancy Hazard

- Sprinkler compatibility with occupancy hazards unclear
- Is old terminology misleading?

Control Mode or Suppression Mode Sprinkler?

Control Mode Sprinkler

Control Mode or Suppression Mode Sprinkler?

Suppression Mode Sprinkler
CMDA vs. CMSA – is there a difference?

CMDA and CMSA Sprinkler Tests

• Objective:
  – Determine through large-scale fire testing if the distinction between CMDA Sprinklers and CMSA Sprinklers can be eliminated.

CMDA and CMSA Sprinkler Tests

• Test Plan:
  – Full-Scale Fire Test Comparison
  – 16 Total Tests (8 Comparison Tests)
  – Open Frame Double-Row Racks w/Class 2 or Standard Plastics
  – K11.2 (K160), Upright Type
  – Low Temperature (Nominal 160 F (70 C))
  – Standard Response
CMDA and CMSA Sprinkler Tests
Ultimate Test Conclusion is that CMDA = CMSA, provided that:
- K-factor
- Orientation
- Nominal Temperature Rating
- Nominal RTI Rating

Are The Same

Movement Towards Sprinklers Based on Occupancy Hazard
- New terminology based on intended use:
  - Storage sprinkler
  - Non-storage sprinkler
  - Special protection sprinkler

Approval Guide will include both sets of terminology

Why Data Sheet 2-0
- Need to update sprinkler terminology
- Opportunity to simplify and improve
- Single global installation standard
- Remove redundant topics
- Guidance on submittal of sprinkler plans

FM Global Property Loss Prevention Data Sheets

March 2018
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Installation Guidelines for Automatic Sprinklers
Data Sheet 2-0 Changes

- Sprigs no longer required
  - Originally recommended to prevent pipe shadow
  - Testing indicated that not an issue
  - Cost savings by removing requirement

Data Sheet 2-0 Changes

- Sprigs no longer required
- Remove area limitation per sprinkler system
  - Driven by pipe schedule limitations
  - No hydraulic basis
  - Reduce number of risers and control valves needed can reduce overall cost

Data Sheet 2-0 Changes

- Sprigs no longer required
- Remove area limitation per sprinkler system
- Requirements for anti-freeze systems
- Guidelines for objects that obstruct sprinklers
DS 2-0 Obstruction Guidelines

Non-storage sprinklers

- Obstruction guidance has not changed
  - Obstruction if object over 4 ft (1.2 m) wide
  - Solid beam construction may need sprinklers in every channel

DS 2-0 Obstruction Guidelines

- Storage Sprinklers
  - Guidelines in DS 2-0 generally no change from DS 2-2 except that also applicable to standard response sprinklers
  - All upright sprinklers follow previous guidance from DS 2-2 (DS 2-2, 2-7 requirements have not changed)

DS 2-0 Obstruction Guidelines

- Storage Sprinklers
  - All pendent sprinklers follow previous guidance from DS 2-2 except for:
    - New figures with relaxed requirements (Fig 35 & 37)
DS 2-0 Obstruction Guidelines

- Storage Sprinklers
  - All pendent sprinklers follow previous guidance from DS 2-2 except for:
    - New figures with relaxed requirements (Fig 35 & 37)
    - Additional figures to support text (Fig 38, 39, 40)
DS 2-0 Obstruction Guidelines

- Storage Sprinklers
  - All pendent sprinklers follow previous guidance from DS 2-2 except for:
    - New figures with relaxed requirements (Fig 35 & 37)
    - Additional figures to support text (Fig 38, 39, 40)
    - Obstructions ≤ ¾ in. (20 mm) wide (Fig 34)
    - New options to deal with existing obstructions
      - Saves on cost of installing barriers and keeping them clean (where needed)
DS 2-0 Obstruction Guidelines

Existing DS 8-9 (2009)

- Three different protection tables
  - One for CMDA sprinklers
  - One for CMSA sprinklers, and
  - One for Suppression Mode sprinklers

- Two different design methods
  - Density / Operating Area for CMDA sprinklers
  - No. of Sprinklers / Minimum Operating Pressure for CMSA & SM sprinklers
Existing DS 8-9 (2009)

- Three different protection tables
- Two different design methods
- Effect of sprinkler spacing on sprinkler flow and pressure via density format
- Design dependent on the least efficient sprinkler via Density format

Why Revise Data Sheet 8-9?

- Opportunity to simplify and improve
- Need to update sprinkler terminology
- Opportunity to base sprinkler designs on a single design format

Movement Towards Sprinklers Based on Occupancy Hazard

- CMDA
- CMSA
- SM

- Single/common design method
- Single/common installation method
- Reduces number of protection tables needed
Movement Towards Single Design Format for Storage

- Prior to 1980s pipe schedule design
- Concept of density born in early 1960s but did not become commonplace until the 1980s
- No. of AS @ Pressure design concept introduced in 1980s
- Research testing over the past few years has demonstrated that various sprinkler attributes are most important factor for sprinkler performance

K Factor

K 5.6  K 25.2

Response Time Index (RTI)

QR  SR
Movement towards Single Design Format - Testing

Common to Both Tests:
- 20 ft (6.0 m) storage height
- 30 ft (9.0 m) ceiling height
- Open frame double-row rack storage
- Cartoned unexpanded plastic commodity
- Ignition under 1 sprinkler

Test 1
- 8 ft (2.4 m) aisle
- 0.8 gpm/ft² (32 mm/min)

Test 2
- 4 ft (1.2 m) aisle
- 0.6 gpm/ft² (24 mm/min)

Which test, if any, will open 5 or fewer sprinklers?

Test No. 1 – 0.80 Density

Test No. 2 – 0.60 Density
Movement Towards Single Design Format

Differences between both tests

Test 1 – 25 Sprinklers
• Upright sprinkler
• K11.2 (K160)
• Standard Response
• Standard Spacing; 10' x 10' (3 m x 3 m)

Loss Expectancy ~ $6,250,000

Test 2 – 1 Sprinkler
• Pendent sprinkler
• K25.2 (K360)
• Quick Response
• Extended Coverage; 14' x 14' (4.2 m x 4.2 m)

Loss Expectancy ~ $500,000

Data Graphs Plots

Orientation

K11.2 (K160) Pendent @ 60 gpm (230 L/min)
10 sprinklers operated

K11.2 (K160) Upright @ 100 gpm (380 L/min)
32 sprinklers operated
Empty Plastic Tote Fire Tests

13.5 ft (4.1 m) high rack storage
30.0 ft (9.0 m) ceiling

K16.8 (K240)
Upright
Quick Response
10 x 10 ft (3 x 3 m)
50 psi = 120 gpm
(3.5 bar = 454 L/min)

K14.0 (K200)
Pendent
Standard Response
10 x 10 ft (3 x 3 m)
75 psi = 120 gpm
(5.2 bar = 454 L/min)
Empty Plastic Tote Fire Tests

K15.8 (K240)  Upright  Quick Response
K14.0 (K200)  Pendant  Standard Response

20 Sprinklers  6 Sprinklers
2,400 gpm  720 gpm
(9,085 L/min) (2,725 L/min)

Movement towards Single Design Format

- What do these tests show?
  - Larger K factor → larger droplets
  - Orientation → water momentum
  - Faster response time → smaller fire to control
  - Density

- FM Global to use No. of Sprinklers at Minimum Operating Pressure as single design format in DS 8-9

Data Sheet 8-9 & Changes in Protection Tables

- Grouping of commodity hazard
  - Class 1 – 3
  - Class 4 – Cartoned Unexpanded Plastics
  - Cartoned Expanded Plastics
  - Expanded Plastics
  - Uncartoned Unexpanded Plastics
  - Uncartoned Expanded Plastics

Class 3 Cartoned Expanded Plastics
Data Sheet 8-9 & Changes in Protection Tables
• Number of protection tables reduced
• All protection options for commodity group in one table
• Design based on actual performance
• Makes it easier to see which options may be better

Data Sheet 8-9 & Changes in Protection Tables
• Protection tables based on
  – No. heads at minimum pressure
  – Ceiling height
  – RTI (standard or quick response)
  – Orientation (upright or pendent)
  – Sprinkler K factor (~ nozzle size)

Data Sheet 8-9 & Changes in Protection Tables
• No storage heights in tables
• No aisle width in tables
• No favorable or non-favorable factors to consider
Data Sheet 8-9 & Changes in Protection Tables

• The # of sprinklers in the design criteria will lead to
  – Hose stream demand
  – Water supply duration

<table>
<thead>
<tr>
<th>Sprinkler Type by Spacing</th>
<th>No. of Sprinklers in Ceiling Design</th>
<th>Hose Demand, gpm (l/min)</th>
<th>Duration, min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Spacing</td>
<td>Up to 12</td>
<td>250 (1,000)</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>13 to 15</td>
<td>500 (1,500)</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>20 or more</td>
<td>500 (1,500)</td>
<td>120</td>
</tr>
<tr>
<td>Extended-Coverage</td>
<td>Up to 6</td>
<td>750 (2,500)</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>7 to 9</td>
<td>500 (1,500)</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>10 or more</td>
<td>500 (1,500)</td>
<td>120</td>
</tr>
</tbody>
</table>

New Technology and Cost of Installations

• Compared to previous standards the new technology and design philosophy leads to:
  – Lower number of sprinklers in design requirements
  – Lower hose demands
  – Lower duration demands

New Technology and Cost of Installations

• Extended Coverage sprinklers installed on wider spacing
  – wider spacing means:
    • fewer sprinklers required
    • fewer branch lines
    • less piping overall
    • fewer connections required
    • less labor for installation
  – Generally a very cost effective solution
**DS 8-9 Future Vision (next 5 years)**

- Eliminate the 10 ft. limitation on storage above the highest in-rack sprinklers
- Establish new in-rack sprinkler protection schemes based on
  - Sprinkler K factor
  - Available pressure
- Eliminate requirement to balance ceiling and in-rack demands

**DS 8-9 Future Vision (next 5 years)**

- Eliminate requirement to hydraulically calculate both ceiling and in-rack sprinkler systems flowing simultaneously
- Add in new technology that emerges
- Revise as needed based on future research & testing

**Retroactivity**

- The guidance in DS 2-0 & DS 8-9 is intended to be applied when:
  - New sprinkler systems are to be installed
  - New client locations are evaluated
  - Existing sprinklered locations have recommendations for protection improvements
  - Existing sprinkler protection is to be modified
The Bottom Line...

Through these changes FM Global is poised to provide our clients with the **most effective protection options**, which are not only **simpler** and **cheaper** to install, but a more **sustainable** choice.

QUESTIONS?