Advances in Sprinkler Technology
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Agenda
• Evolution of FM Global Fire Protection Standards
• Changes in Terminology for Sprinkler Categories
• Movement Away from Density and Demand Area
• Data Sheet 2-0 Installation Guidelines for Automatic Sprinklers
• Data Sheet 8-9 & Changes in Protection Tables
• Retroactivity of Data Sheets 2-0 and 8-9

What is FM Global?
• FM Global’s market share includes:
  – 45% of the Fortune 100 Companies
  – 42% of the Fortune 500 Companies
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

- Fire Technology Lab
- Natural Hazards Lab
- Electrical Lab
- Materials Lab
- Hydraulics Lab
- Multimedia Center
- Two Movable Ceilings
- Humidity Control

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**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)

**Example of Full Scale Fire Testing**

- Evaluate existing European Codes at that time
- Protection of rack storage
- 55 ft (16.5 m) rack storage
- 60 ft (18 m) ceiling height
- Cartoned unexpanded plastic
- Standard response in-rack sprinklers

**55 ft (16.5 m) rack storage – test fails**
55 ft (16.5 m) rack storage – test passes

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 insured clients
- Recommendations offered when hazards encountered are not protected in accordance with appropriate data sheet
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>
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<td>6</td>
<td>180</td>
</tr>
<tr>
<td>8</td>
<td>278</td>
</tr>
</tbody>
</table>

Change in Industrial Practices

End of World War II:
- Steel construction for buildings
- Forklift trucks
- Storage racks constructed of steel
- Increase in plastic materials stored

FM Global Research on Sprinkler Protection
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

1970's Research Projects

- “Residential” sprinkler & quick response thermal element
- Water penetration through fire plume (fire suppression)
Then came...

- The K11.2 (K160) “Large-Drop” Sprinkler
- Control Mode Specific Application (CMSA) sprinkler
- Design format changed - Number of sprinklers at minimum pressure

Installation guidelines for these sprinklers evolved into DS 2-7

Then came...

- A bunch of Control Mode Specific Application (CMSA) sprinklers
  - K16.8 (K240), K19.6 (K280), K25.2 (K360), K25.2EC (K360EC)

Then came...

- CMSA improved protection options but...
- Fire tests showed suppression not always possible
Then came...

- First Early Suppression Fast Response (ESFR) Sprinkler
- K14.0 (K200) pendent

ADD Concept

Example of ADD and deflector design
Example of ADD Testing and Deflectors

Then came...

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

Installation standard for these sprinklers was DS 2-2

Suppression Mode Sprinkler Installation Guidelines
Advances in Sprinkler Technology

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

So where we were in 2009?

• Three different sprinkler categories
• Three sets of installation guidelines
• Terminology implies performance

Changes in Terminology for Sprinkler Categories

• Old Terminology:
  • CMDA – Control Mode Density Area
  • CMSA – Control Mode Specific Application
  • SM – Suppression Mode

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Changes in Terminology for Sprinkler Categories

- Sprinkler compatibility with occupancy hazards unclear
- Old terminology misleading
- Actual performance can be otherwise
  - Control Mode sprinklers → fire suppression
  - Suppression Mode sprinklers → fire control

Control Mode Sprinkler Achieves Suppression

Suppression Mode Achieves Control
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

• Total of 8 Comparison Tests (16 Tests Total) between CMDA and CMSA – Open Sprinkler Differential for Acceptable Comparisons:
  • 1 Sprinkler Differential: 3 Comparison Tests
  • 3 to 4 Sprinklers Differential: 2 Comparison Tests
  • 10 Sprinklers Differential: 2 Comparison Tests
  • 1 Test Series Where Both Tests Terminated Before Fire Control

CMDA and CMSA Sprinkler Tests

Test Conclusions

• Ultimate Conclusion: CMDA = CMSA Provided That:
  – K-factor
  – Orientation
  – Nominal Temperature Rating
  – Nominal RTI Rating
  Are The Same

Changes in Terminology for Sprinkler Categories

• New terminology based on intended use:
  – Storage sprinkler
  – Non-storage sprinkler
  – Special protection sprinkler

• Approval Guide will include both sets of terminology
Changes in Terminology for Sprinkler Categories

- CMDA
- CMSA
- SM

- Storage sprinklers
- Single/common design method
- Single/common installation method
- Reduces number of protection tables needed

Movement away from Density and Demand Area

- Prior to 1980s pipe schedule design
- Concept of density born in early 1960s but did not become commonplace until the 1980s
- Research testing over the past few years has demonstrated that design density is not the most important factor for sprinkler performance

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/ft\(^2\) (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 gpm/psi\(^{0.5}\) (Lpm/bar\(^{0.5}\))

### Density and Sprinkler Spacing

- **Density affects minimum flow and pressure at sprinkler**

\[
\begin{align*}
Q &= D \times S \times L, \text{ gpm (Lpm)} \\
P &= \left[\frac{D \times S \times L}{K}\right]^2, \text{ psi (bar)}
\end{align*}
\]

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

\[
\text{Total No. of AS} = \frac{\text{Demand Area}}{(S \times L)} \\
\text{No. of AS per branchline} = SF \times \left(\frac{\text{Demand Area}}{S}\right)^{0.5}/S
\]

- \(SF\): 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

Density/Demand Area Format

- Full scale fire tests conditions:
  - Upright standard response sprinkler
  - Use smallest K-factor allowed for hazard area
  - Use maximum allowable area spacing of sprinkler
- Protection tables → driven by least efficient sprinkler
- Sprinkler spacing less than maximum → lower flows and pressures than used in testing

Movement away from Density and Demand Area
Which sprinkler will perform better?

**Movement away from Density and Demand Area**

**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)

**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)

**Test 2 – 1 Sprinkler**
- Pendent sprinkler
- K25.2 (K360)
- Quick Response
- Extended Coverage; 14’ x 14’ (4.2 m x 4.2 m)
Movement away from Density and Demand Area

• What does this test show?
  – Larger K factor → larger droplets
  – Orientation → water momentum
  – Faster response time → smaller fire to control
  – Density

Data Graphs Plots

Orientation

K11.2 (K160) Pendent @ 60 gpm (230 L/min)  K11.2 (K160) Upright @ 100 gpm (380 L/min)

10 sprinklers operated 32 sprinklers operated
**K factor**

- K16.8 (K240) @ 80 gpm (300 L/min)
- K11.2 (K160) @ 80 gpm (300 L/min)

15 sprinklers operated 29 sprinklers operated

**Response Time Index**

- K14 (K200) OR @ 100 gpm (380 L/min)
- K14 (K200) SR @ 120 gpm (450 L/min)

11 sprinklers operated uncontrolled – test terminated

**Temperature Rating**

- K11.2 (K160) 155 F (68 C) 80 gpm (300 L/min)
- K11.2 (K160) 286 F (140 C) 80 gpm (300 L/min)

24 sprinklers operated uncontrolled – test terminated
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)

1970'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
- 0.6 gpm/ft² (24 mm/min)

82 sprinklers open
2000's Sprinkler Technology

- 20 ft (6.0 m) Storage
- 30 ft (9.0 m) Ceiling
- Cartoned Unexpanded Plastic Commodity
- Open-Frame Double-Row Rack
- 4 ft (1.2 m) Wide Aisle
- K25.2EC (K360EC) Pendent Ceiling Sprinkler
- Quick-Response
- 0.6 gpm/ft² (24 mm/min)

Sprinklers with the proper attributes can:

- Provide Better Protection
- Be More Cost Effective
- Be More Sustainable
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

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

- 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)

Previously
24 inches

Previously
36 inches
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)
• 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)
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 maintaining
Existing DS 8-9

• 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

• Effect of sprinkler spacing on sprinkler flow and pressure
• Design dependent on the least efficient sprinkler
Why Revise Data Sheet 8-9

• Need to update sprinkler terminology
• Need to replace density in design criteria
• Opportunity to simplify and improve

Data Sheet 8-9 & Changes in Protection Tables

• Grouping of commodity hazard
  – Class 1 – 3
  – Class 4 – Cartoned Unexpanded Plastics
  – Cartoned Expanded Plastics
  – Uncarton Unexpanded Plastics
  – Uncarton Expanded Plastics

Why group Class 1 up through Cartoned Plastics?

• In 2006 a K5.6 (K80) sprinkler protecting open-frame DRR to 15 ft (4.5 m) under a 30 ft (9.0 m) ceiling requires the following pressures:
  – Class 1: 12 psi @ MR Sprinkler
  – Class 2: 17 psi @ MR Sprinkler
  – Class 3: 22 psi @ MR Sprinkler
  – Class 4: 39 psi @ MR Sprinkler
  – Cartoned Plastics: 115 psi @ MR Sprinkler
  – Cartoned Plastics (2008): 204 psi @ MR Sprinkler
Why group Class 1 up through Cartoned Plastics?

- Cartoned plastics in open-frame DRR to 15 ft (4.5 m) under a 30 ft (9.0 m) ceiling requires 0.80 gpm/ft² (32 mm/min) over 3,000 ft² (280 m²).
  - K8.0 (K115) : 100 psi @ MR Sprinkler
  - K11.2 (K160) : 50 psi @ MR Sprinkler
  - K16.8 (K240) : 22 psi @ MR Sprinkler
  - K25.2 (K360) : 10 psi @ MR Sprinkler

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 are better options
Data Sheet 8-9 & Changes in Protection Tables

- No storage heights in tables
- No aisle width in tables
- No favorable factors

<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>220 (875)</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>13 to 19</td>
<td>500 (1,900)</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>20 or more</td>
<td>500 (1,900)</td>
<td>120</td>
</tr>
<tr>
<td>Extended-Coverage</td>
<td>Up to 8</td>
<td>220 (875)</td>
<td>60</td>
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<td></td>
<td>9 to 18</td>
<td>500 (1,900)</td>
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<tr>
<td></td>
<td>10 or more</td>
<td>500 (1,900)</td>
<td>120</td>
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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

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
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 unsprinklered locations are to be retrofitted with sprinkler protection
  - 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 less expensive to install, but a more sustainable choice.