Sprinkler Skipping
Will “skipping” be a factor in the performance of the sprinkler (sprinkler in the fire area being cooled by adjacent activated sprinklers preventing it from operating)?

The best wail for a system to fail is to “Skip” critical sprinklers from operating in the “Core” fire area.
“I just wish we could teach the first sprinkler to count to 10 before it discharges water”

Steve Meyer - 1996
Skipping Occurs When:

1. The higher the clearance is between what's burning and the sprinkler prevents droplets from reaching the hazard and cools the surrounding sprinklers.
2. Strong fire plume velocities carry water and cooling back up to the surrounding sprinklers.
3. Water droplet size and velocity fails to penetrate the fire plume and gets carried back up to the surrounding sprinklers.
4. Obstructions to sprinkler discharge may cause #2 and #3
K 5.6

7 psi (0.5 bar)
Technical Report

Evaluation of the Skip-Resistant Sprinkler Concept
(Sprinkler Skipping Workshop Report)

By
Benjamin Ditch, John L. de Ris, Hong-Zeng Yu

Prepared for
FM Global
Norwood, MA 02062

October 2008

Figure 12: Sprinkler operation terminology.
Pan Fire Tests

Table 8: Abbreviated large-scale heptane pan fire test summary.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>System Pressure [bar (psi)]</th>
<th>Sprinkler Shields Installed</th>
<th>No. Sprinkler Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3.4 (50)</td>
<td>No</td>
<td>17</td>
</tr>
<tr>
<td>15</td>
<td>3.4 (50)</td>
<td>No</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>3.4 (50)</td>
<td>Yes</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>3.4 (50)</td>
<td>Yes</td>
<td>6</td>
</tr>
</tbody>
</table>

Each test was conducted with K-14 pendent sprinklers located on a ceiling that was 9.14 m (30 ft) above a 2.1 x 2.1 m (7 x 7 ft) heptane pan.

Fire Source: 2.1m x 2.1m pan

Figure 13: Comparison of sprinkler operation patterns from pan fires with a discharge pressure of 3.4 bar (50 psi) – Tests 5, 7, 8, 15.
High Ceiling Tests

Fuel Arrangement: FMRC Class 2 commodity
Fuel Height: 2.26 m
Clearance to ceiling: 15.4 m
Arrangement of fuel package: 8 by 8, solid pile, 2 tiers
Density: 12 mm/min
Sprinklers: K115, RTI 140 \((m\cdot s)^{1/2}\) Standard Response, Upright
Spacing: 3.0 m x 3.0 m
Side View of Fuel Array

Tests 1 and 2

Tests 3, 4 and 5

Wood Pallet (0.13 m high)

Class II

Group A Plastics
Plan View of Fuel Array – Test 1

- Sprinkler Location
- Ignition Location

(Not to scale)
Plan View of Sprinkler Operation – Test 1

- Sprinkler positions (3-m by 3-m spacing)
- Operated sprinklers: Total of 15. Numbers correspond to opening sequence.
- Ignition location at base of array.

Fuel Array Outline

Operating Sequence | Time (min:s)
--- | ---
1 | 2:58
2 | 5:30
3 | 5:31
4 | 5:41
5 | 5:43
6 | 5:45
7 | 5:46
8 | 5:53
9 | 5:54
10 | 5:55
11 | 6:00
12 | 6:10
13 | 6:24
14 | 6:54
15 | 7:03
16-oz Polystyrene Plastic Jars in compartmented cardboard cartons
Plan View of Fuel Array – Test 3 & 4
// Description of Full Scale Fire Test 3

// Fuel Arrangement: FMRC Group A Plastics
// Fuel Height: 1.73 m
// Clearance to ceiling: 15.9 m
// Arrangement: 2 by 8, solid pile, 1 tier
// Density: 12 mm/min
// Sprinklers: K115, RTI 140 (m-s)\(^{1/2}\) Standard Response element, Upright
// Spacing: 3.0 m x 3.0 m
Plan View of Sprinkler Operation – Test 3

- Sprinkler positions (3-m by 3-m spacing)
- Operated sprinklers: Total of 26. Numbers correspond to opening sequence. The test was terminated at 9 min.
- Ignition location at base of array.
Results Test 3

Number of Sprinklers Operated: 26 !
Skipping of Sprinklers: extreme
Test terminated at 9 minutes before it yielded conclusive results

Key Take Away: Test failed
Description of Full Scale Fire Test 5

intended to provide a reference point for future work

// Fuel Arrangement: FMRC Group A Plastics identical to test4
// Fuel Height: 1.73 m
// Clearance to ceiling: 16.6 m
// Clearance to deflector: 16.4 m
// Arrangement: 2 by 8, solid pile, 1 tier
// Density: 18 mm/min
// Sprinklers: K= 360 (EC-25), RTI 28 (m-s)^{1/2} Fast Response element, Upright
// Spacing: 6.1 m x 6.1 m
EC-25 (Extended Coverage Extra Hazard Sprinkler)

// Control Mode (Density/Area)
// Extended Coverage
// K-factor – 360 LPM/bar$^{1/2}$
// RTI: 28 (m-s)$^{1/2}$ – Fast Response element
// Temperature Ratings 74° C or 101° C
// Position: Upright
// Finish: Natural Brass
// Pipe Thread Connection: 1” NPT or ISO 7-R1
Plan View of Sprinkler Operation – Test 5
Results Test 5

Number of Sprinklers Operated: 1
Ceiling temperature: Within acceptable levels
Fire damage: Fire well confined to ignition array
No Skipping of sprinklers since only one operated

Key Take Away: Favorable results, fire losing intensity at 2 min. 10s., one head operating, fire well confined but additional test needed to verify protection scheme
Obstructions

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>OBSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4&quot; BAR JOIST (8 IN. DOWN)</td>
</tr>
<tr>
<td>2</td>
<td>1-1/2&quot; BRIDGING (8 IN. DOWN)</td>
</tr>
</tbody>
</table>

20 FT HIGH PLATFORM

40 ft

10 ft
PROTECTION SYSTEM K-14 ESFR SPRINKLER

CEILING SPRINKLERS ONLY
PENDENT INSTALLATION
10 FT X 10 FT SPACING
14 IN. DEFLECTOR CLEARANCE
75 PSI SYSTEM PRESSURE
NOMINAL RTI 50
165 ºF
K=14
0.70 IN. ORIFICE
Baseline

- TOTAL NUMBER OF SPRINKLERS
  - EIGHT (8) DURING TEST (Max)
  - BENCHMARK - ONE
- FIRE DAMAGE
  - IGNITION ARRAY ONLY
- CEILING STEEL TEMPERATURE
  - LESS THAN 1000 °F
PROTECTION SYSTEM K-14 ESFR SPRINKLER

PLAN VIEW

4'

N

Bar Joist

Bar Joist

Sprinkler

PLAN VIEW
TEST 1

-Bar Joist Obstruction (4” Chord)
-Rack Storage - Group A Cartoned Unexpanded Plastic
-Scenario
  - 30 ft Storage - Ignition Below One
  - 40 ft Building
-75 PSI - K14 ESFR
ESFR Obstucted Test

30 ft (9.1 m) Group A Cartoned unde a
40 ft (12.2 m) ceiling

4 inch (100 mm) wide bottom chord of truss
Located 8 inches below the ESFR deflector

K14 (K200) Pendent ESFR
@ 75 psi (5.2 bar) Ignition under one
RESULTS - TEST 1

29 SPRINKLER OPERATIONS

PEAK TEMPERATURES
- 1550 °F CEILING GAS
- 344 °F CEILING STEEL
<table>
<thead>
<tr>
<th>NO.</th>
<th>TIME (M:SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0:39</td>
</tr>
<tr>
<td>2 - 12</td>
<td>1:30 - 2:00</td>
</tr>
<tr>
<td>13 - 22</td>
<td>2:01 - 2:30</td>
</tr>
<tr>
<td>23 - 26</td>
<td>2:31 - 3:00</td>
</tr>
<tr>
<td>27 - 28</td>
<td>3:01 - 3:30</td>
</tr>
<tr>
<td>29</td>
<td>3:40</td>
</tr>
</tbody>
</table>
## IGNITION ZONE SPRINKLER ACTUATIONS - TEST 1

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>1:41</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>2:42</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>3:40</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1:51</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0:39</td>
<td>X</td>
</tr>
<tr>
<td>19</td>
<td>1:53</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1:57</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>2:52</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>3:38</td>
<td></td>
</tr>
</tbody>
</table>

Note: The 'X' indicates an actuation that did not occur as expected.
TEST 2

- BRIDGING OBSTRUCTION (1.5” W)
- RACK STORAGE - GROUP A CARTONED UNEXPANDED PLASTIC
- SCENARIO
  - 30 FT STORAGE - IGNITION BELOW ONE
  - 40 FT BUILDING
- 75 PSI - K14 ESFR
RESULTS - TEST 2

27 SPRINKLER OPERATIONS

PEAK TEMPERATURES

- 1162 °F CEILING GAS
- 227 °F CEILING STEEL
### SPRINKLER ACTUATION SEQUENCE - TEST 2

<table>
<thead>
<tr>
<th>NO.</th>
<th>TIME (M:SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0:42</td>
</tr>
<tr>
<td>2</td>
<td>1:30 - 2:00</td>
</tr>
<tr>
<td>3 - 21</td>
<td>2:01 - 2:30</td>
</tr>
<tr>
<td>22</td>
<td>2:31 - 3:00 (2:42)</td>
</tr>
<tr>
<td>23 - 26</td>
<td>3:01 - 3:30</td>
</tr>
<tr>
<td>27</td>
<td>3:55</td>
</tr>
</tbody>
</table>
IGNITION ZONE SPRINKLER ACTUATIONS - TEST 2

(20) 2:24
(25) 3:28
(26) 3:28

(9) 2:12
(1) 0:42
(23) 3:07

(27) 3:55
(22) 2:42
(DNO)
# TEST RESULTS

<table>
<thead>
<tr>
<th></th>
<th>NO. SPRINKLERS</th>
<th>FIRE DAMAGE</th>
<th>MAX. STEEL TEMP.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEST 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(JOIST)</td>
<td>29</td>
<td>+IGNITION ARRAY</td>
<td>344 °F</td>
</tr>
<tr>
<td><strong>TEST 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(BRIDGING)</td>
<td>27</td>
<td>+IGNITION ARRAY</td>
<td>227 °F</td>
</tr>
</tbody>
</table>
Droplets Ability to Penetrate the Fire Plume

22 MPH (45 KPH)
Small Drops are Carried Back to Ceiling - May Skip or Prevent Adjacent Sprinklers from Opening

22 MPH (45 KPH)
K 25 EC

7 psi (0.5 bar)
CONCLUSIONS

• The higher the clearance is between what's burning and the sprinkler prevents droplets from reaching the hazard and cools the surrounding sprinklers.
• Strong fire plume velocities carry water and cooling back up to the surrounding sprinklers.
• Water droplet size and velocity fails to penetrate the fire plume and gets carried back up to the surrounding sprinklers.
• Obstructions to sprinkler discharge may cause #2 and #3