Experience from fire sprinkler tests in a shuttle storage system

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Vertical Lift Systems

Vertical Carousel Storage Systems
**Fire hazards**

A fire may start in:

- Electrical motors, wiring or electrical connections, electronic equipment or components.
- Bearings or other components of the extractor or the drive that ignites the stored goods.
- The stored goods.
- Due to incendiarism.
Documented fire tests in shuttle storage systems

- Tests by SP Fire Research for the Viking Corporation.
- Tests by SP Fire Research for IKEA Services AB.
Ministry of Defence Estates (MOD)

- Are using Carbon Dioxide systems but there is no experience on how effective they are.
- Unable to insure risks on a commercial basis.
- The loss of key parts or components could affect the operational capacity of armed forces.
MOD Defence Estates

Fire test series I

- Carbon Dioxide system with a nozzle at the top of the unit.
- First two tests: Fires in the motor and control panel. Successful.
- Third test: Fire on the trays. The Carbon Dioxide system had no effect as the trays prevented adequate ingress of the agent. The fire burnt for five hours, until all combustibles were consumed.
- The fire department was alerted but the fire fighters were unable to extinguish the fire. Water sprays were applied to the external surfaces to provide cooling.
- Problem: Lack of sight into the unit and virtually no access. The seat and spread of the fire could only be guessed.
MOD Defence Estates

Fire test series II

- Two additional tests, one with water mist and one with Inergen.
- Fire on the trays.
- The water mist system was unable to extinguish a fire, despite the use of several different system configurations.
- The Inergen system was designed with special injection and screening nozzles. The system was designed to establish and sustain the extinguishing concentration over an extended period. Several tests proved that system could extinguish all fire and sustaining the concentration in excess of 30 minutes.
- Based on the results, MOD Defence Estates has published a Policy Instruction on the protection and use of these types of storage systems.
Tests by SP Fire Research for the Viking Corporation

- Three fire tests were conducted in 2008 in order to develop a deluge water spray system to be certified by VdS Schadenverhütung.
- Open spray nozzles were installed at the short sides of the unit combined with flat spray nozzles at the top of the unit.
- All nozzles were activated by a deluge valve opened by the heat from a fire.
- The system managed to control all fire with a total water flow rate of approximately 700 liter/minute at a 4 bar pressure.
- Manual fire-fighting was required after each test.

Reference: Brandposten no. 38, 2008
Tests by SP Fire Research for IKEA Services AB

- Length: 4.38 m.
- Depth: 2.97 m.
- Height: 7.95 m.
- The unit was supplied by Kardex, Bellheimer Metallwerk GmbH.
- Installed inside the fire test hall by staff from Kardex Scandinavia AB.
The objective of the tests

Can sprinklers installed at the top of the unit:

- Protect its integrity during a fire?
- Limit the possibilities for fire spread to adjacent objects or building parts?

Minimum requirement in order to judge the test results as acceptable:

- The unit is not allowed to collapse.
- No full or partial rupture of any of the wall or ceiling panels or joints between these panels is allowed.
- No rupture of the hatch is allowed.
- No fire spread to adjacent objects or combustible material is allowed.
- Note: Fire extinguishment was not expected!
Two tests were conducted

Test 1: The trays inside the unit were compactly stored. The free vertical distance between the fire tray and the tray above was 25 mm.

Test 2: One tray was removed such that the free vertical distance between the fire tray and the tray above was 300 mm.

The hatch to the unit was closed (as it would be in practice).
Instrumentation and measurements

• Gas temperatures inside the unit.
• Surface temperatures on the walls and ceiling of the unit.
• Surface temperature of a Plate Thermometer positioned 1.2 m in front of the back wall.
• Oxygen (O2) concentration at two measurement positions.
• Sprinkler system operating pressure and flow rate.
• Smoke detector installed at the ceiling of the unit.
• Thermal imaging camera positioned in front of the back wall.
The steel trays

Important: Drain holes to the sides
Typical commodity stored at IKEA

• Smaller items.
• Flat packages, for example with kitchen or wardrobe doors.
• No high-value commodity!
The EUR Std plastic commodity
Plastic crates
Packages of kitchen doors
Packages of particle boards
The sprinkler system

- Four pendent, Quick Response standard coverage spray sprinklers.
- K-factor of 115 (K8.0).
- 3 mm glass bulb with a nominal operating temperature of 68°C (155°F).
Test 1: The measured oxygen concentration

Oxygen concentration (vol-%) vs Time (min)

- C34 - 1.3 m above floor
- C35 - 3.2 m above floor

Sprinkler on
Test terminated
Test 1: The ceiling gas temperature
Test 1: Thermal imaging camera

62:00 (a few seconds prior activation)

63:13 (one minute after activation)

72:13 (10 minutes after activation)
Test 2: 300 mm distance
Test 2: 04:00 [min:sec]
Test 2: The measured oxygen concentration

Test 2 (2010-05-27)

Sprinkler on

Oxygen concentration (vol-%)

Time (min)

- C34 - 1.3 m above floor
- C35 - 3.2 m above floor
Test 2: The ceiling gas temperature

![Graph showing the ceiling gas temperature over time for Test 2 on 2010-05-27. The graph indicates a peak temperature of approximately 150°C and a time duration of about 30 minutes.]
Test 2: Thermal imaging camera

08:50 (a few seconds prior activation)

09:53 (one minute after activation)

18:53 (10 minutes after activation)
# Test results

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activation times [min:sec]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoke alarm</td>
<td>07:15</td>
<td>02:49</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; sprinkler (only)</td>
<td>62:13</td>
<td>08:53</td>
</tr>
<tr>
<td>Discharge duration time</td>
<td>30:00</td>
<td>50:00</td>
</tr>
<tr>
<td><strong>Minimum oxygen concentration [vol-%]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 m above floor</td>
<td>13.5</td>
<td>12.4</td>
</tr>
<tr>
<td>2.3 m above floor</td>
<td>14.0</td>
<td>11.0</td>
</tr>
<tr>
<td><strong>Gas and surface temperatures [°C]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak wall temp. (C1)</td>
<td>405</td>
<td>600</td>
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<tr>
<td>Peak average wall temp. (C1-C22)</td>
<td>56</td>
<td>59</td>
</tr>
<tr>
<td><strong>Plate Thermometer temperature [°C]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak temperature</td>
<td>49</td>
<td>72</td>
</tr>
</tbody>
</table>
Conclusions from the tests

- Very slow fire growth rate in Test 1. Sprinkler activated after about 62 minutes. The fire was not extinguished.
- More rapid fire growth rate in Test 2. Sprinkler activated after about 9 minutes. The fire was extinguished by the combustion gases (several minutes after sprinkler activation).
- Only one sprinkler activated (both tests).
- The sprinkler system maintained the structural integrity of the unit.
- The high temperature exposure was only local.
- The probability for fire spread to adjacent (horizontal distance of at least 1.2 m) combustible objects or material is very small.
- No water was observed in the trays, indicating that the top trays collected all water from the sprinkler and drained it to the side.
Sprinkler design recommendations

• Four sprinklers should be installed.
• A minimum clearance of 0.5 m, measured from the rims of the top trays to the deflector of the sprinklers should apply.
• Standard coverage, spray pendent, quick response sprinklers with a K-factor of 115 should be used.
• The system should be designed for four flowing sprinklers at an operating pressure of 1.0 bar.
Unit design recommendations and improvement

- A minimum vertical clearance of 0.5 m, measured from the rims of the top trays to the deflector of the sprinklers is required.
- Achieved by either a physical blockage of the space for the trays or by a fail-safe programming of the unit.
- Individual wall panels should be joined with six M6 bolts instead of the current four M6 bolts.
- Drainage of the trays (to the sides) should be arranged!
- Additional small holes at the sides of the trays to allow water drainage.
Practical recommendations regarding manual fire suppression

- Electrically disconnect the unit upon detection of a fire or upon sprinkler activation.
- The unit should NOT be opened during a fire.
- Use water from fire hoses to cool the enclosure from the outside if the integrity and stability of the unit is endangered.
- Use an infrared (IR) thermal imaging camera to help locate the fire.
- Drill (small) holes and insert lances at the spot of the fire. Use water to fight the fire.
- Allow time for cooling before the unit is opened and ventilated.
Thank you!