Project Goals and Accomplishments

- Establish protection options for diluted water miscible ignitable liquids in glass bottles
  - Palletized storage
  - Rack storage

- Conducted tests to define
  - Ceiling-only protection for palletized storage
    - 9.1 m (30 ft) and 12.2 m (40 ft) ceiling
  - Ceiling and in-rack protection for rack storage
What Is a Water Miscible Liquid?

- A liquid can be mixed in **all** proportions with water
  - As water concentration increases
    - Flash point and fire point will increase
    - Heat of combustion will decrease

- Limited number of liquids
  - 3-carbon or less alcohol (IPA, EtOH, MeOH)
  - Acetone, propylene glycol
<table>
<thead>
<tr>
<th>Group</th>
<th>Volume Percent Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alcohol (short chain)</td>
</tr>
<tr>
<td>1</td>
<td>71 – 100</td>
</tr>
<tr>
<td>2</td>
<td>51 – 70</td>
</tr>
<tr>
<td>3</td>
<td>31 – 50</td>
</tr>
<tr>
<td>4</td>
<td>21 – 30</td>
</tr>
<tr>
<td>5</td>
<td>0 - 20</td>
</tr>
</tbody>
</table>

- 20 full scale fire tests
  - 14 rack storage tests (99% - 20% IPA in plastic)
  - 3 palletize storage tests (99% IPA in plastic)
  - 2 rack storage tests (50% EtOH in glass)
  - 1 palletized storage test (50% EtOH in glass)

- Goals
  - Define new protection criteria
### Protection Options – Rack Storage

<table>
<thead>
<tr>
<th>Container Size</th>
<th>Container Type</th>
<th>Packaging</th>
<th>Storage / Roof Height Limit</th>
<th>Protection Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 4 L (1 gal)</td>
<td>Plastic/Glass</td>
<td>Cartoned</td>
<td>7.6 m (25 ft) / 9 m (30 ft)</td>
<td>K200-QR, K160-SR + In-racks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.6 m (25 ft) / &gt; 9 m (30 ft)</td>
<td>Protection Scheme A</td>
</tr>
<tr>
<td>≤ 25 L (6.5 gal)</td>
<td>Plastic/Glass</td>
<td>Any</td>
<td>Unlimited</td>
<td>Protection Scheme A</td>
</tr>
</tbody>
</table>
# Protection Options – Palletize Storage

<table>
<thead>
<tr>
<th>Container Size</th>
<th>Container Type</th>
<th>Packaging</th>
<th>Storage / Roof Height Limit</th>
<th>Protection Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>(&lt; 1.75 \text{ L (59 oz)})</td>
<td>Plastic</td>
<td>Cartoned</td>
<td>(6.1 \text{ m (20 ft) / 9 m (30 ft)})</td>
<td>K200-QR, K160</td>
</tr>
<tr>
<td>(&lt; 750 \text{ ml (25 oz)})</td>
<td>Glass</td>
<td>Cartoned</td>
<td>(4.9 \text{ m (16 ft) / 9 m (30 ft)})</td>
<td>K200-QR</td>
</tr>
</tbody>
</table>
Recent Testing
Alcohol in Glass Bottles

- Clients bottled, stored, and shipped distilled spirits
- Classified as group 3, water miscible ignitable liquid
  - 50% (v/v) denatured alcohol, 100-proof
  - Filled in 1.75 L (59 fl. oz.) glass bottles
Test Commodity

- **1.75 L Glass Bottles in Cartons**
  - Industry standard cartons from supplier
  - 6 bottles per carton

- **Pallet-load**
  - 36 Cartons per pallet
  - 141 cm (55.5 in.) high
  - Stretch-wrapped in place
Test Commodity

- Class 2 Commodity
  - Corrugated paper carton outside
  - Non-combustible sheet metal liner
- Used at periphery of array
- Assess fire propagation but not representative of hazard
Palletized Testing
Palletized Test Arrangement

- 6 parallel rows of stacked commodity
  - Cartoned alcohol to 5.0 m (16.5 ft)
  - Class 2 commodity to 4.8 m (15.7 ft)
- 30 cm (12 in.) longitudinal flues
  - No transverse flues
  - Pallets overhung by ~8 cm (3 in.)
Palletized Test Plan

- K200 (K14) QR Upright 74 °C (165 °F)
  - Ceiling-only protection
  - Vary design pressure

- 9.1 m (30 ft) and 12.2 m (40 ft) ceiling heights
Evaluation Criteria

- Extent of fire damage
  - Contained within alcohol commodity
  - Array collapse was considered
- Number of sprinkler operations
- Steel temperatures
9.1 m Ceiling Test 1

- 5.0 m (16.5 ft) storage / 9.1 m (30 ft) ceiling
- K200 (K14) QR Upright 74 °C (165°F) @ 1.2 bar (18 psi)
  - 24 mm/min (0.6 gpm/ft²) design density
- Test Video
9.1 m Ceiling Test 1 Results

- Initial collapse @ 5 min
  - 8 operating sprinklers
- Fire propagated to extent of array
  - 12 stacks collapsed during test
- 13 total sprinkler operations
- Fire was extinguished at test termination
9.1 m Ceiling Test 2

- 5.0 m (16.5 ft) storage / 9.1 m (30 ft) ceiling
- K200 (K14) QR Upright 74 °C (165 °F) @ 3.4 bar (50 psi)
  - 41 mm/min (1.0 gpm/ft²) design density
- Results
  - 1 sprinkler operation
  - No collapse during test
12.2 m Ceiling Test

- 5.0 m (16.5 ft) storage / 12.2 m (40 ft) ceiling
- K200 (K14) QR Upright 74 °C (165°F) @ 5.2 bar (75 psi)
  - 49 mm/min (1.2 gpm/ft²) design density
- Test Video
12.2 m Ceiling Test Results

- Initial collapse @ 20 min
  - 1 operating sprinklers
- 3 total sprinkler operations
- Fire was extinguished at test termination
Rack Storage Testing
Rack Storage Strategy

- Client interested in rack storage up to 12.8 m (42 ft)
- Strategy to install IRAS up to 5.5 m (18 ft) vertical increments
  - 3.7 m (12 ft) storage below 1st level IRAS
  - 5.5 m (18 ft) storage below 2nd level IRAS
  - 3.7 m (12 ft) storage above with ceiling sprinklers
- Test subset of the arrangement
Rack Storage Test Arrangement

- 9.1 m (30 ft) storage / 10.7 m (35 ft) ceiling
- IRAS installed at 5.5 m (18 ft)
  - Face and flues, 1.2 m (4 ft) spacing
  - K115 (K8.0) @ 114 lpm (30 gpm)
- Ceiling protection for top 3.7 m (12 ft) storage
  - K160 (K11.2) @ 2 bar (28 psi)
- Test Video
Rack Storage Test Results

- 2 IRAS operated (52 s, 3 min 8 s)
- No propagation above IRAS
- No ceiling sprinklers operated
- Fire contained to ignition area
Conclusions From Testing

- Cartoned alcohol in 1.75 L (59 fl. oz.) glass bottles
- Palletized storage to 5.0 m (16.5 ft) can be protected
  - 9.1 m (30 ft) and 12.2 m (40 ft) ceiling
  - Collapse of stacks likely for all protection options
  - Floor level pool fire protected at lower pressure
- IRAS protection for 5.5 m (18 ft) vertical section
  - Ceiling level sprinklers not evaluated
Future Work

- **Data Sheet 7-29, Table 16**
  - Rack storage below 9.1 m (30 ft) ceiling
  - Ceiling-only protection, ≥ K200 (K14)
    - 12 sprinklers @ 5.2 bar (75 psi)
      - K200 (K14) = 49 mm/min (1.2 gpm/ft²)
      - K360 (K25) = 90 mm/min (2.2 gpm/ft²)

- **Conduct test with K360 (K25) at equivalent density**
  - 1.6 bar (23 psi)
  - 49 mm/min (1.2 gpm/ft²)
Distilled Spirits Cased Goods Storage

QUESTIONS?

Global Research Update: High Challenge Storage Protection