IGNITABLE LIQUID STORAGE IN PORTABLE CONTAINERS

Table of Contents

1.0 SCOPE ....................................................................................................................... 4
  1.1 Changes ................................................................................................................... 4
2.0 LOSS PREVENTION RECOMMENDATIONS .......................................................... 4
  2.1 Introduction ............................................................................................................. 4
     2.1.1 Liquid Evaluation .............................................................................................. 4
     2.1.2 General Recommendations .............................................................................. 4
     2.1.3 Atypical Ignitable Liquids ............................................................................... 5
  2.2 Construction and Location ...................................................................................... 8
  2.3 Occupancy .............................................................................................................. 15
     2.3.1 Housekeeping .................................................................................................. 15
     2.3.2 Ventilation ...................................................................................................... 15
  2.4 Protection ............................................................................................................... 16
     2.4.1 General ............................................................................................................ 16
     2.4.2 Metal Containers (Including IBCs) Larger than 60 gal (230 L) ...................... 18
     2.4.3 Metal Containers Larger than 6.5 gal (25 L) Up to and Including 60 gal (230 L) 20
     2.4.4 Metal Containers of 6.5 gal (25 L) or Less .................................................... 20
     2.4.5 Protection of Plastic, Composite (Plastic-Metal), or Other Combustible Containers:
        General .................................................................................................................. 27
     2.4.6 Composite (blow molded bottle in a wire cage on a wood or steel pallet) IBC Storage of
        Liquids with a Flash Point At or Above 200°F (93°C) or Alcohol in Racks .......... 29
     2.4.7 Plastic, Glass, or Other Combustible/Brittle Containers Up to and Including 60 gal (230 L) 29
     2.4.8 Yard Storage: Any Container Type ................................................................. 37
  2.5 Operation and Maintenance ................................................................................... 37
  2.6 Training .................................................................................................................. 37
  2.7 Human Factor ....................................................................................................... 37
  2.8 Ignition Source Control ......................................................................................... 39
3.0 SUPPORT FOR RECOMMENDATIONS .................................................................. 40
  3.1 Liquid Evaluation .................................................................................................. 40
     3.1.1 Water-Miscible Liquids ................................................................................... 43
     3.1.2 Emulsions ........................................................................................................ 44
     3.1.3 Viscous Liquids/Viscous Mixtures .................................................................. 44
     3.1.4 Liquids with Boiling Point Below 100°F (38°C) .............................................. 45
     3.1.5 Liquids with Specific Gravity Above 1 ............................................................. 45
     3.1.6 Atypical Ignitable Liquids .............................................................................. 45
  3.2 Construction and Location .................................................................................... 46
  3.3 Ventilation ............................................................................................................. 47
  3.4 Protection .............................................................................................................. 47
     3.4.1 General .......................................................................................................... 47
     3.4.2 Automatic Sprinklers ..................................................................................... 47
     3.4.3 Special Protection Systems ............................................................................ 47
  3.5 Ignition Source Control ....................................................................................... 48
4.0 REFERENCES ......................................................................................................... 48
  4.1 FM Global ............................................................................................................. 48
  4.2 NFPA .................................................................................................................... 49
  4.3 Other .................................................................................................................... 49

APPENDIX A GLOSSARY OF TERMS ....................................................................... 49
Fig. 1. Location and construction of ignitable liquid storage buildings and cutoff rooms. ................. 8
Fig. 2. Water spray protection for steel columns ............................................................................... 12
Fig. 3a. Double row rack sprinkler layout - drum protection scheme ................................................ 56
Fig. 3b. Double row rack sprinkler layout - drum protection scheme ................................................ 57
Fig. 3c-1. Multiple row rack sprinkler layout - drum protection scheme ........................................... 58
Fig. 3c-2. Multiple row rack sprinkler layout - drum protection scheme ........................................... 59
Fig. 3d. Double row rack sprinkler layout - drum protection scheme ................................................ 60
Fig. 3e. Double row rack sprinkler layout - drum protection scheme ................................................ 61
Fig. 3f. Double row rack sprinkler layout - drum protection scheme ................................................ 62
Fig. 3g. Double row rack sprinkler layout - drum protection scheme ................................................ 63
Fig. 3h. Double row rack sprinkler layout - IBC protection scheme .................................................. 64
Fig. 4a. Single row rack sprinkler layout - small metal containers ..................................................... 65
Fig. 4b. Double row rack sprinkler layout - small metal containers .................................................... 66
Fig. 4c. Multiple row rack sprinkler layout - small metal containers .................................................. 67
Fig. 4d. Multiple row rack sprinkler layout - small metal containers .................................................. 68
Fig. 5a. Single row rack sprinkler layout - small metal containers ....................................................... 69
Fig. 5b. Double row rack sprinkler layout - small metal containers ..................................................... 70
Fig. 5c. Multiple row rack sprinkler layout - small metal containers .................................................... 71
Fig. 6a. Single row rack sprinkler layout - small metal containers ....................................................... 72
Fig. 6b. Double row rack sprinkler layout - small metal containers ..................................................... 73
Fig. 7a. Single row rack sprinkler layout - water-miscible liquids in small metal containers .................. 74
Fig. 7b. Double row rack sprinkler layout - water-miscible liquids in small metal containers ............. 75
Fig. 7c. Multiple row rack sprinkler layout - water-miscible liquids in small metal containers ........... 76
Fig. 8a. Single row rack sprinkler layout - quick response sprinklers protection scheme ..................... 77
Fig. 8b. Double row rack sprinkler layout - quick response sprinklers protection scheme .................. 78
Fig. 8c. Double row rack sprinkler layout - quick response sprinklers protection scheme .................. 79
Fig. 8d. Double row rack sprinkler layout - quick response sprinklers protection scheme ................. 80
Fig. 8e. Multiple row rack sprinkler layout - quick response sprinklers protection scheme ................ 81
Fig. 8f. Multiple row rack sprinkler layout - quick response sprinklers protection scheme ................. 82
Fig. 8g. Multiple row rack sprinkler layout - quick response sprinklers protection scheme ................ 83
Fig. 8h. Multiple row rack sprinkler layout - quick response sprinklers protection scheme ................ 84
Fig. 8i. Multiple row rack sprinkler layout - quick response sprinklers protection scheme ................. 85
Fig. 8j. Multiple row rack sprinkler layout - quick response sprinklers protection scheme ................. 86
Fig. 8k. Multiple row rack sprinkler layout - quick response sprinklers protection scheme ................. 87
Fig. 8l. Multiple row rack sprinkler layout - quick response sprinklers protection scheme ................. 88
Fig. 9a. Single Row Rack Storage of Group 4 Water-miscible Liquids ............................................... 89
Fig. 9b. Double Rack Storage of Group 4 Water-miscible Liquids I ..................................................... 90
Fig. 10a. Single Row Rack Storage of Group 4 Water-miscible Liquids .............................................. 91
Fig. 10b. Double Row Rack Storage of Group 4 Water-miscible Liquids ............................................ 92
Fig. 11. Double Row Rack Storage of Group 3 Water-miscible Liquids ............................................. 93
Fig. 12a. Single row rack sprinkler layout - fire protection scheme A .................................................. 95
Fig. 12b. Single row rack sprinkler layout - fire protection scheme A .................................................. 96
Fig. 12c. Double row rack sprinkler layout - fire protection scheme A ............................................... 97
Fig. 12d. Multiple row rack sprinkler layout - fire protection scheme A ............................................. 98
Fig. 13a. Single row rack sprinkler layout - fire protection scheme B .................................................. 100
Fig. 13b. Single row rack sprinkler layout - fire protection scheme B .................................................. 101
Fig. 13c. Double row rack sprinkler layout - fire protection scheme B ............................................... 102
Fig. 13d. Multiple row rack sprinkler layout - fire protection scheme B ............................................. 103
Fig. 14a. Single row rack sprinkler layout - fire protection scheme C .................................................. 105
List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1. Glycol Water Mixtures</td>
<td>8</td>
</tr>
<tr>
<td>Table 2. Location and Construction for Ignitable Liquid Storage</td>
<td>10</td>
</tr>
<tr>
<td>Table 3a. Drainage and Containment Requirements for Liquid Storage in</td>
<td>13</td>
</tr>
<tr>
<td>Metal Containers in Cutoff Rooms/Buildings</td>
<td></td>
</tr>
<tr>
<td>Table 3b. Drainage and Containment Requirements for Liquid Storage in</td>
<td>14</td>
</tr>
<tr>
<td>Plastic Containers in Cutoff Rooms/Buildings</td>
<td></td>
</tr>
<tr>
<td>Table 4. Palletized or Solid-Pile Storage of Ignitable Liquids in</td>
<td>19</td>
</tr>
<tr>
<td>Relieving-Style Metal Containers Larger than 60 gal (230 L)</td>
<td></td>
</tr>
<tr>
<td>Table 5. Rack Storage of Ignitable Liquids in Relieving-Style Metal</td>
<td>19</td>
</tr>
<tr>
<td>Containers Larger than 60 gal (230 L)</td>
<td></td>
</tr>
<tr>
<td>Table 6. Rack Storage of Ignitable Liquids in Metal Containers larger</td>
<td>21</td>
</tr>
<tr>
<td>than 6.5 gal (25 L) up to and including 60 gal (230 L) with Aisles a</td>
<td></td>
</tr>
<tr>
<td>Minimum of 8 ft (2.4 m) Wide</td>
<td></td>
</tr>
<tr>
<td>Table 7. Palletized/Solid-Pile Storage of Ignitable Liquids in Metal</td>
<td>22</td>
</tr>
<tr>
<td>Containers Larger than 6.5 gal (25 L) up to and including 60 gal (230</td>
<td></td>
</tr>
<tr>
<td>L)</td>
<td></td>
</tr>
<tr>
<td>Table 8. Rack Storage of Ignitable Liquid in Metal Containers Up to</td>
<td>24</td>
</tr>
<tr>
<td>and Including 6.5 gal (25 L) with Aisles a Minimum of 8 ft (2.4 m)</td>
<td></td>
</tr>
<tr>
<td>Wide</td>
<td></td>
</tr>
<tr>
<td>Table 9. Protection for Any Ignitable Liquid in Relieving-Style Metal</td>
<td>25</td>
</tr>
<tr>
<td>Containers Up to and Including 6.5 gal (25 L), Excluding Ignitable</td>
<td></td>
</tr>
<tr>
<td>Liquids with a Boiling Point Below 100°F (38°C)</td>
<td></td>
</tr>
<tr>
<td>Table 10. Palletized/Solid-Pile Storage of Liquids in Metal Containers</td>
<td>26</td>
</tr>
<tr>
<td>Up to and Including 6.5 gal (25 L)</td>
<td></td>
</tr>
<tr>
<td>Table 11. Shelf Storage of Liquids in Metal Containers Up to and</td>
<td>26</td>
</tr>
<tr>
<td>Including 6.5 gal (25 L)</td>
<td></td>
</tr>
<tr>
<td>Table 12. Fire Protection Criteria for Ignitable Liquids in Plastic</td>
<td>28</td>
</tr>
<tr>
<td>or Glass Containers</td>
<td></td>
</tr>
<tr>
<td>Table 13. Rack Storage of Liquids in Composite IBCs (blow molded</td>
<td>29</td>
</tr>
<tr>
<td>bottle in a wire cage on a wood or steel pallet)</td>
<td></td>
</tr>
<tr>
<td>Table 14. Rack Storage of Liquids in Plastic or Glass Containers</td>
<td>31</td>
</tr>
<tr>
<td>with Flash Points Below 200°F (93°C)</td>
<td></td>
</tr>
<tr>
<td>Table 15. Rack Storage of Liquids in Plastic or Glass Containers</td>
<td>32</td>
</tr>
<tr>
<td>with Flash Points At or Above 200°F (93°C)</td>
<td></td>
</tr>
<tr>
<td>Table 16. Rack Storage of Group 1, 2, 3, and 4 Water-Miscible Liquids</td>
<td>33</td>
</tr>
<tr>
<td>in Plastic or Glass Containers</td>
<td></td>
</tr>
<tr>
<td>Table 16. Rack Storage of Group 1, 2, 3, and 4 Water-Miscible Liquids</td>
<td>34</td>
</tr>
<tr>
<td>(Continued)</td>
<td></td>
</tr>
<tr>
<td>Table 17. Palletized/Solid-Pile Storage of Liquids with Closed-Cup</td>
<td>35</td>
</tr>
<tr>
<td>Flash Points At or Above 200°F (93°C) in Plastic Containers</td>
<td></td>
</tr>
<tr>
<td>Table 18. Palletized/Solid-Pile Storage of Groups 1 through 4 Water-</td>
<td>36</td>
</tr>
<tr>
<td>Miscible Liquids in Plastic or Glass Containers</td>
<td></td>
</tr>
<tr>
<td>Table 19. Electrical Equipment Ratings, Lift Truck Ratings and</td>
<td>39</td>
</tr>
<tr>
<td>Ventilation Rates for Ignitable Liquids</td>
<td></td>
</tr>
<tr>
<td>Table 20. Ignitable Liquid Spill Fire Data: Comparison of Various</td>
<td>42</td>
</tr>
<tr>
<td>Spill Rates and Liquids</td>
<td></td>
</tr>
<tr>
<td>Table 21. Ignitable Liquid Pool Fire Data: Comparison of Fixed Pool</td>
<td>42</td>
</tr>
<tr>
<td>Diameter Fires for Different Liquids with Fixed Liquid Depth</td>
<td></td>
</tr>
<tr>
<td>Table 22. Water-Miscible Liquid Groupings</td>
<td>44</td>
</tr>
</tbody>
</table>
1.0 SCOPE

This data sheet covers the storage of chemically stable liquids that can burn (i.e., ignitable liquids) stored in portable, non-pressurized metal, glass, fiberboard, plastic, or composite containers of any size.

For the purposes of this document, the term “ignitable liquid” is used to represent any liquid that has a measurable fire point. Also, the term “flash point” always refers to the closed-cup flash point unless stated otherwise.

This data sheet does not cover the following subjects:

A. The dispensing of ignitable liquids. Use Data Sheet 7-32, Ignitable Liquid Operations, to evaluate all ignitable liquid dispensing operations.

B. Combustible solids or unstable liquids (i.e., liquids that have the potential to self-react or polymerize).

C. Liquids that have a flash point but no fire point (see Appendix A).

D. Aerosols. See Data Sheet 7-31, Storage of Aerosol Products.

E. Distilled spirits in wooden barrels.

F. Stationary tanks. See Data Sheet 7-88, Ignitable Liquid Storage Tanks.

G. Compressed or flammable liquefied gases. See Data Sheet 7-50, Compressed Gases in Cylinders; Data Sheet 7-53, Liquefied Natural Gas (LNG); and Data Sheet 7-55, Liquefied Petroleum Gas (LPG) in Stationary Installations.

1.1 Changes

April 2020. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 Liquid Evaluation

2.1.1.1 Protect all ignitable liquids, mixtures, emulsions, or semi-solids in storage that have measurable flash points and fire points in accordance with this data sheet. The following are criteria for evaluating some liquids:

A. Liquids, mixtures, and emulsions that do not exhibit a fire point (see Appendix A) are not ignitable liquids.

B. Evaluate and group water-miscible ignitable liquids in accordance with Table 22 and Section 3.1.1. Group 5 water-miscible liquids are not ignitable liquids.

C. Protect viscous mixtures (see Section 3.1.3 for definition) of ignitable liquids with solids in metal containers per the recommendations in Data Sheet 8-9, Storage of Class 1, 2, 3, 4 and Plastic Commodities, for Class 3 Commodities.

D. Protect viscous mixtures (see Section 3.1.3 for definition) of ignitable liquids with solids in plastic containers per the recommendations in Data Sheet 8-9, Storage of Class 1, 2, 3, 4 and Plastic Commodities, for cartoned unexpanded plastic.

E. Protect emulsions (mixtures that do not separate) having more than 20% ignitable liquid in a water base in accordance with their flash point. (Emulsions with up to 20% ignitable liquid in a water base are not considered ignitable liquids regardless of flash or fire point.)

F. Protect materials that are solid at room temperature (68°F [20°C]) in accordance with the applicable FM Global data sheet.

2.1.2 General Recommendations

2.1.2.1 Arrange, locate, and protect dispensing operations in accordance with Data Sheet 7-32, Ignitable Liquid Operations. Ensure cutoff rooms or detached buildings with both ignitable liquid storage and dispensing meet all applicable recommendations in this data sheet and in Data Sheet 7-32.
2.1.2.2 Limit storage in ignitable liquid rooms to ignitable liquids unless the other items do not present a fire hazard greater than the liquid storage, and they are not of high value. Design the protection scheme for the entire storage room or building for the highest-challenge storage.

2.1.2.3 Do not mix storage of ignitable liquids with oxidizers or flammable gas.

2.1.2.4 Any level of aerosol product may be stored with ignitable liquids in maximum 1 qt (0.9 L) metal containers as long as the provided fire protection scheme, isolation, and construction features are fully adequate for both storage types.

2.1.2.5 Handle, store, and protect partially full containers as full containers. Store empty containers that have not been cleaned and purged outside the facility.

2.1.3 Atypical Ignitable Liquids

2.1.3.1 Liquids with Closed-Cup Flash Points At or Above 450°F (232°C)

2.1.3.1.1 Confirm the closed-cup flash point of the stored liquid using one of the following test methods:

A. ASTM D56, Standard Test Method for Flash Point by Tag Closed Tester

B. ASTM D93, Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

C. ISO 2719, Petroleum Products and Lubricants - Determination of Flash Point - Pensky-Martens Closed Cup Method

Have the test repeated three times. If the closed-cup flash point is at or above 450°F (232°C) for the average of all three tests, the liquid can be protected in accordance with this data sheet.

2.1.3.1.2 Protect liquids with confirmed closed-cup flash points at or above 450°F (232°C) that are pumped or heated above 150°F (65°C) in accordance with the recommendations for liquids with a flash point at or above 200°F (93°C) in Data Sheet 7-32, Ignitable Liquid Operations.

2.1.3.1.3 Protect liquids with confirmed closed-cup flash points at or above 450°F (232°C) that are stored in plastic, glass, or metal containers of less than 40 gal (150 L) in accordance with the fire protection tables within this standard.

2.1.3.1.4 Protect liquids with a confirmed closed-cup flash point at or above 450°F (232°C) that are stored in fixed steel tanks as follows:

A. Provide a curb around the tank sized for the full contents of the tank.

B. Drainage is not needed.

C. A cutoff room is not needed.

D. The curb may be adjacent to surrounding occupancies.

E. Provide ceiling sprinklers and design to protect the surrounding occupancy. Use a minimum ceiling sprinkler design of not less than 7 psi (0.5 bar) using twenty-five (25) K8.0 (K115) sprinklers if standard spray sprinklers are provided.

2.1.3.1.5 Protect liquids with confirmed closed-cup flash points at or above 450°F (232°C) that are stored in portable metal containers of 40 gal (150 L) or more as follows:

A. Rack or palletized storage may be in Locations 1-5 per Figure 1.

B. Drainage or containment is not needed.

C. Do not vertically mix liquid storage with solid commodities in palletized or rack arrays.

D. Provide a minimum of 5 ft (1.5 m) horizontal clearance between liquid and non-liquid storage.

E. Provide ceiling sprinklers and design to protect the surrounding occupancy. Use a minimum ceiling sprinkler design of not less than 7 psi (0.5 bar) using twenty-five (25) K8.0 (K115) sprinklers if standard spray sprinklers are provided.

2.1.3.1.6 Protect liquids with confirmed closed-cup flash points at or above 450°F (232°C) that are stored in 40-60 gal (150-230 L) plastic containers as follows:
A. Storage may be in Locations 1-5 per Figure 1.

B. Drainage or containment is not needed.

C. Do not vertically mix liquid storage with solid commodities in palletized or rack arrays.

D. Provide a minimum of 10 ft (3 m) horizontal clearance between liquid and non-liquid storage.

E. For single-pallet-high container storage, provide sprinkler protection over the storage designed to provide at least 7 psi (0.5 bar) using twenty-five (25) K11.2 (K160) sprinklers if standard spray sprinklers are provided; for higher storage, protect as an uncartoned, unexpanded plastic per Data Sheet 8-9, *Storage of Class 1, 2, 3, 4, and Plastic Commodities*.

2.1.3.1.7 Protect liquids with confirmed closed-cup flash points at or above 450°F (232°C) that are stored in composite IBCs (only blow-molded plastic bottle in a wire cage with a wooden or steel pallet) as follows:

A. Storage may be in Locations 1-5 per Figure 1.

B. Provide a curb around the IBC storage area sized for the contents of four IBCs. Drainage is not needed.

C. Do not vertically mix liquid storage with solid commodities in palletized or rack arrays.

D. There are no storage height limitations.

E. Provide a minimum of 10 ft (3 m) horizontal clearance between liquid and non-liquid storage.

F. Provide ceiling sprinklers and design to protect the surrounding occupancy. Use a minimum ceiling sprinkler design of not less than 7 psi (0.5 bar) using twenty-five (25) K8.0 (K115) sprinklers if standard spray sprinklers are provided.

2.1.3.1.8 Protect liquids with confirmed closed-cup flash points at or above 450°F (232°C) that are stored in bag-in-box style IBCs (a corrugated board box on a wooden pallet with a plastic bag of some type in the box) as follows:

A. Storage may be in Locations 1-5 per Figure 1.

B. Provide a curb around the IBC storage area sized for the contents of twelve IBCs. Drainage is not needed.

C. Do not vertically mix liquid storage with solid commodities.

D. Limit the storage arrangement to 2 high palletized IBCs. A rack storage option does not exist at this time.

E. Provide a minimum of 10 ft (3 m) horizontal clearance between liquid and non-liquid storage.

F. Provide ceiling sprinklers and design to protect the surrounding occupancy. Use a minimum ceiling sprinkler design of not less than 7 psi (0.5 bar) using twenty-five (25) K8.0 (K115) sprinklers if standard spray sprinklers are provided.

2.1.3.1.9 Protect liquids with confirmed closed-cup flash points at or above 450°F (232°C) that are stored in composite IBCs fitted with plastic pallets, or all plastic IBCs as follows:

A. Storage may be in Locations 1-5 per Figure 1.

B. Provide containment around the IBC storage area sized for the contents of all stored IBCs. Drainage is not needed.

C. Do not store in racks.

D. Limit storage height to one unit high.

E. Provide a minimum of 10 ft (3 m) horizontal clearance between liquid and non-liquid storage.

F. Provide sprinkler protection over the storage designed for exposed expanded plastic in accordance with Data Sheet 8-9, *Storage of Class 1, 2, 3, 4, and Plastic Commodities*. 

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2.1.3.2 Silicone Fluids and Silicone Emulsions

Silicone fluids are also referred to as siloxanes or methyl siloxanes and these materials should be treated as straight chain silicones as referenced in this section. Methylhydrogen siloxanes and organofunctional silanes are higher hazard and should be treated as traditional ignitable liquids.

2.1.3.2.1 Silicone emulsions consisting of up to 50% silicone fluid in water are not considered ignitable liquids. Lab-scale testing of these emulsions did not produce a flash point or fire point.

2.1.3.2.2 Protect straight chain silicone fluids with a closed-cup flash point of 450°F (232°C) or more in accordance with 2.1.3.1.

2.1.3.2.3 Protect all other silicone fluids as an ignitable liquid in accordance with their flash point and this data sheet.

2.1.3.3 Paste Ink

2.1.3.3.1 Protect paste ink storage in accordance with Data Sheet 7-96, Printing Plants.

2.1.3.4 Water-Based Polyurethane Foam Packaging Systems

This section only applies to the water-based packaging systems. There are other versions of these materials in industry for manufacturing many types of urethane foam products. Protect liquids used in these operations as ignitable liquids based on their flash point.

Polymethylene polyphenyl isocyanate, diphenylmethane diisocyanate or polymeric MDI or PMDI is an ignitable liquid; however, the actual fire hazard created is limited. A pool of PMDI will only produce limited flame heights regardless of pool size. A local ignition will spread across the entire pool surface. The level of ceiling sprinkler protection over a pool fire is not critical; containment is. Unfortunately, a fire involving this liquid is still expected to fail adjacent composite IBCs creating a growing fire involving the empty IBCs which require a significant sprinkler design.

Polyol is not considered an ignitable liquid unless it is blended with oil (the polyol used in packaging systems is generally not blended with oil).

2.1.3.4.1 Protect storage of PMDI in metal or plastic containers in accordance with its flash point and this data sheet.

2.1.3.4.2 For areas where PMDI and polyol are used, adhere to the recommendations in Data Sheet 7-32, Ignitable Liquid Operations.

2.1.3.5 Butterfat

2.1.3.5.1 Protect butterfat as an ignitable liquid with a closed-cup flash point above 450°F (232°C).

2.1.3.6 Unsaturated Polyester Resin (UPR)

2.1.3.6.1 UPR mixtures with 50% or less styrene can be protected in a palletized array up to 3 relieving-style drums (10 ft [3m]) high without a foam-water sprinkler system (see Table 7 and Table Note 3). All other construction, containment, drainage, and ignition source control recommendations apply based on the container size and mixture flash point. Protect other container sizes of UPR or UPR with higher styrene content based on the container and the liquid flash point in accordance with this data sheet.

2.1.3.7 Propylene and Ethylene Glycol Mixtures

2.1.3.7.1 Use Table 1 to determine the recommended fire protection for glycol (propylene or ethylene) and glycol-water mixtures. Glycols are high flash point, water-miscible, ignitable liquids. They do not exhibit a fire point in glycol-water mixtures with 80% or less glycol. Glycol-water mixtures with less than 80% glycol can still impact the growth and overall severity of a fire if they spill onto absorbent packaging materials.
Table 1. Glycol Water Mixtures

<table>
<thead>
<tr>
<th>Glycol Content</th>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;80%</td>
<td>Protect as a Group 3 water-miscible liquid.</td>
</tr>
<tr>
<td>≤80% and &gt;35%</td>
<td><strong>Plastic/Glass Containers:</strong> Protect as a cartoned unexpanded plastic. <strong>Metal Containers:</strong> Protect for the provided packaging.</td>
</tr>
<tr>
<td>≤35%</td>
<td><strong>Plastic/Glass Containers:</strong> Protect as a non-ignitable liquid in a plastic container. <strong>Metal Containers:</strong> Protect for the provided packaging.</td>
</tr>
</tbody>
</table>

2.1.3.8 Semi-Solid Liquids

2.1.3.8.1 Protect butter or margarine in any container as a Class 2 commodity using Data Sheet 8-9.

2.1.3.8.2 Protect liquid salad dressings with less than 50% oil content in any packaging as a Class 3 commodity using Data Sheet 8-9.

2.1.3.8.3 Protect any semi-solid oil-based product (e.g., shortening, deep-frying fat, grease, etc.) in accordance with its measured flash point and this data sheet.

2.2 Construction and Location

Isolate ignitable liquid storage by distance or construction so it does not expose important buildings or facilities, and in turn is protected from fires originating elsewhere. The extent of the necessary isolation depends on such factors as the size of the container, the container construction type, and the physical properties of the liquid. The provision of passive fire protection features is an integral part of the total approach to controlling ignitable liquid hazards.

2.2.1 Locate and construct ignitable liquid storage cutoff rooms and detached buildings in accordance with Table 2, Figure 1, and Sections 2.2.2 through 2.2.8. The table and figure only apply to storage occupancies. Evaluate manufacturing occupancies that utilize ignitable liquids in accordance with Data Sheet 7-32, Ignitable Liquid Operations.

Note: Table 2 and Figure 1 assume both the exposing building/room and the exposed building are adequately sprinklered.

Definitions:
Location 1 - Detached Building
Location 2 - Outside Cut-Off Room
Location 3 & 4 - Inside Cut-Off Room
Location 5 - General Purpose Warehouse

Fig. 1. Location and construction of ignitable liquid storage buildings and cutoff rooms.
2.2.2 FM Approved prefabricated ignitable liquids storage buildings (PILSB) may be used as an alternate to a permanently constructed cut-off or detached ignitable liquids storage room, subject to the following limitations.

A. The PILSB must provide all of the active and passive protection features recommended in this standard (e.g., fire rating; containment and drainage; ventilation; ignition source control; and automatic fire protection).

B. Maintain all containers at least \( \frac{1}{2} \) the storage height away from the door opening.

C. Do not use PILSB units with explosion venting inside a building.

2.2.3 Use FM Approved ignitable liquid storage cabinets to hold limited quantities of ignitable liquids. Arrange the cabinets as follows:

A. Restrict ignitable liquid quantities as necessary so that the cabinet will contain the largest expected liquid release (e.g., largest metal container and contents of all plastic and glass containers).

B. Limit the amount of liquid storage to the Approval limit.

C. Cutoff is not needed from storage or non-storage occupancies.

D. Provide a minimum of 20 ft (6 m) separation between cabinets and non-liquid warehouse areas.

E. Do not put cabinets within non-liquid rack storage arrangements. Protect the surrounding occupancy in accordance with FM Global data sheets.

F. Do not dispense ignitable liquids from containers located in storage cabinets unless the area the cabinet is located in meets the recommendations in Data Sheet 7-32, *Ignitable Liquid Operations*. 
Table 2. Location and Construction for Ignitable Liquid Storage

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Flash Point, Liquid Type (Note 1)</th>
<th>Container Size</th>
<th>Storage Location</th>
<th>Wall Location</th>
<th>Construction Type or Fire Rating (Note 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>Any</td>
<td>≤6.5 gal (25 L)</td>
<td>1, 2, 3, 4, 5</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;6.5 gal (25 L)</td>
<td>1</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>A</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3, 4</td>
<td></td>
<td>A</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>Plastic, Glass, or Other Combustible Containers</td>
<td>≤200°F (93°C)</td>
<td>&gt;6.5 gal (25 L)</td>
<td>1, 2, 3, 4, 5</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤6.5 gal (25 L)</td>
<td>1, 2, 3, 4, 5</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;6.5 gal (25 L)</td>
<td>1</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>A</td>
<td>NC</td>
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<td></td>
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<td>B</td>
<td>-</td>
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<td></td>
<td></td>
<td>3, 4</td>
<td></td>
<td>A</td>
<td>NC</td>
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<td>B</td>
<td>2 hour</td>
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<td></td>
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<td></td>
<td></td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>Water- miscible</td>
<td>&gt;200°F (93°C)</td>
<td>≤1 gal (4 L)</td>
<td>1, 2, 3, 4, 5</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;1 gal (4 L)and ≤6.5 gal (25 L)</td>
<td>1</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
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<td>2</td>
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<td>A</td>
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<td>A</td>
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<td></td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;6.5 gal (25 L)</td>
<td>1</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
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<td>2</td>
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<td></td>
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<td>3, 4</td>
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<td>A</td>
<td>NC</td>
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<td></td>
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<td>B</td>
<td>2 hour</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>&lt;200°F (93°C)</td>
<td>≥200°F (93°C)</td>
<td>≤2 oz (60 ml)</td>
<td>1, 2, 3, 4, 5</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;2 oz (60 ml)</td>
<td>1</td>
<td>A, B, C</td>
<td>NC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>A</td>
<td>NC</td>
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<td></td>
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<td></td>
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<td>B</td>
<td>-</td>
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<tr>
<td></td>
<td></td>
<td>3, 4</td>
<td></td>
<td>A</td>
<td>NC</td>
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<td>B</td>
<td>2 hour</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes:
1. For liquids with flash points above 450°F (232°C) in containers larger than 40 gal (150 L), see Section 2.1.3.1.
2. NC = Noncombustible.

2.2.4 Locate storage areas on ground floors. Upper floors introduce problems of access for firefighting, floor leakage, and transportation of drums through main areas. Do not use basement locations because they are difficult to ventilate, drain, or enter during fires. A room with a recessed floor is not considered a below-grade room.

2.2.5 Locate interior or exterior cutoff rooms next to loading/shipping docks to prevent the creation of an ignitable liquid fire hazard along liquid transportation routes in buildings that are not protected for the hazard. Provide the cutoff rooms with their own shipping doors. Provide space in the cutoff rooms for staging of product before it is placed in storage or while it is waiting for shipment.
Provide loading docks at which ignitable liquid containers are staged with construction, protection, containment, and emergency drainage as recommended by this data sheet. The term "staged" in this context excludes continuous movement of containers from inside the shipping vehicle directly to the properly designed storage area.

2.2.6 For any storage requiring cutoff per Table 2 and protected in accordance with Tables 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, and 18, construct cutoff rooms and their walls as follows:

A. Design walls to be liquid-tight so released liquids (e.g., ignitable liquids, sprinkler discharge, inside hose streams) will be contained.

B. Design walls for the hydraulic pressure created by the contained liquid level.

C. Provide at least one outside access way to the cutoff room.

D. Protect necessary interior openings with a normally closed, automatically closing fire door. Locate the fire door on the storage side of the wall. A less desirable alternative is to arrange a normally open fire door to automatically close actuated by a fire inside or directly outside the room.

2.2.7 For any storage requiring cutoff per Table 2 and protected in accordance with Table 12, construct cutoff rooms and their walls as follows:

A. Provide masonry or concrete construction.

B. Design walls to be liquid-tight so released liquids (e.g., ignitable liquids, sprinkler discharge, inside hose streams) will be contained.

C. Design walls for the hydraulic pressure created by the contained liquid level.

D. Provide at least one outside access way to the cutoff room.

E. When a direct connection is needed between the cutoff room and the main building, provide an enclosed walkway designed to prevent the flow of liquid from entering the main building if the drainage and/or containment systems are overwhelmed.

F. Protect interior openings leading to cutoff rooms with a normally closed, automatically closing fire door. Locate the fire door on the storage side of the wall. A less desirable alternative is to arrange a normally open fire door to automatically close actuated by a fire inside or directly outside the room.

G. Protect steel columns located inside detached buildings or cutoff rooms using one of the following methods or an equivalent:

1. Provide fireproofing rated for one hour or the expected fire duration, whichever is greater. Provide fireproofing that is rated for a hydrocarbon fire exposure. (See Data Sheet 1-21, Fire Resistance of Building Assemblies.)

2. Provide automatic (fusible link) sidewall sprinklers or water spray protection for the full height of the column, as shown in Figure 2. The figure shows nozzles staggered on opposite sides of a wide-flange column on 20 ft (6.1 m) centers. The black outline in the top view shows the reentrant space (web and flanges) that must be wetted for the column to be cooled effectively. Provide a minimum 0.3 gpm/ft² (12 mm/min) over the wetted area of the column ("wetted area" is the surface area on the three sides of the reentrant space formed by the column web and flanges). The wetted area protected by a sprinkler extends from the sprinkler down to the next sprinkler on the same side of the column.
2.2.8 Provide an FM Approved roof covering that consists of a Class 1 internal fire resistance (see Data Sheet 1-29, Roof Deck Securement and Above-Deck Roofing Components) and an ASTM E108 Class A rated external fire resistance (see Data Sheet 1-29) for all detached buildings or cutoff rooms.

A. For cutoff rooms that have ceilings below the main building’s roof, provide a ceiling assembly that has the same fire resistance as the interior walls of the cutoff room.

B. For cutoff rooms that have wooden roof assemblies, isolate the wooden roof with the same fire resistance as needed for the interior walls of the cutoff room. Provide sprinklers in any created combustible spaces in accordance with Data Sheet 1-12, Ceilings and Concealed Spaces.

2.2.9 Provide masonry or concrete construction for all 2-hour rated walls. Provide impact protection for 1-hour fire rated walls constructed of low-impact strength materials (e.g., gypsum board) to a height equal to the storage height when storage is adjacent to the wall, or 5 ft (1.5 m) when the storage is away from the walls.

2.2.10 Provide noncombustible wall construction with no openings for the wall on the main building/warehouse side for 10 ft (3 m) beyond each side of an exterior cutoff room (i.e., Wall ‘C’ for Location 2 in Figure 1).

2.2.11 Provide drainage and/or containment for cutoff rooms or buildings that store ignitable liquids in accordance with Table 3.

2.2.11.1 Liquids with a viscosity greater than 10,000 cp only require containment.

2.2.11.2 Design drainage and containment systems according to Data Sheet 7-83, Drainage and Containment Systems for Ignitable Liquids. Do not include hose stream demands in the drainage or containment design unless inside hose stations are provided. Use 50 gpm (190 L/min) for one hose station, or 100 gpm (380 L/min) for more than one in the fire area.

2.2.11.3 Protection schemes that require the use of foam-water sprinkler systems only need containment. If a foam-water sprinkler system is installed, design the containment to hold up all liquid discharge in the contained area for at least 20 minutes.
Table 3a. Drainage and Containment Requirements for Liquid Storage in Metal Containers in Cutoff Rooms/Buildings

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Flash Point, Liquid Type (Note 1)</th>
<th>Container Size</th>
<th>Drainage and/or Containment Options and Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>≥200°F (93°C)</td>
<td>≤6.5 gal (25 L)</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Or Water-miscible</td>
<td>&gt;6.5 gal (25 L)</td>
<td>1. Provide containment and drainage or containment alone arranged to prevent spilled liquid plus actual sprinkler discharge (Note 2) from leaving the room/building of origin for 30 minutes. At a minimum, provide 3 in. (7.6 cm) of containment. Or 2. Provide an FM Approved foam-water sprinkler system or compressed air foam (CAF) system. Provide containment designed to keep spilled liquid plus actual sprinkler discharge (Note 2) in the room-of-origin for 20 minutes. At a minimum, provide 3 in. (7.6 cm) of containment.</td>
</tr>
<tr>
<td></td>
<td>&lt;200°F (93°C)</td>
<td>≤6.5 gal (25 L)</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Or</td>
<td>&gt;6.5 gal (25 L)</td>
<td>1. Provide containment and drainage or containment alone arranged to prevent spilled liquid plus actual sprinkler discharge (Note 2) from leaving the room/building of origin for 30 minutes. At a minimum, provide 3 in. (7.6 cm) of containment. Or 2. Provide an FM Approved foam-water sprinkler system or compressed air foam (CAF) system. Provide containment designed to keep spilled liquid plus actual sprinkler discharge (Note 2) in the room-of-origin for 20 minutes. At a minimum, provide 3 in. (7.6 cm) of containment.</td>
</tr>
<tr>
<td></td>
<td>&lt;60 gal (230 L)</td>
<td>≤6.5 gal (25 L)</td>
<td>1. Provide emergency floor drainage and containment designed in accordance with Data Sheet 7-83 to remove the spilled liquid plus actual sprinkler discharge (Note 2). Arrange the drains to ensure a liquid spill could not cover more than the sprinkler operating area. At a minimum, provide 3 in. (7.6 cm) of containment. Or 2. Provide an FM Approved foam-water sprinkler system or compressed air foam (CAF) system. Provide containment designed to keep spilled liquid plus actual sprinkler discharge (Note 2) in the room-of-origin for 20 minutes. At a minimum, provide 3 in. (7.6 cm) of containment.</td>
</tr>
<tr>
<td></td>
<td>&gt;60 gal (230 L)</td>
<td>&gt;6.5 gal (25 L)</td>
<td>Provide containment designed in accordance with Data Sheet 7-83, Drainage and Containment Systems for Ignitable Liquids, and sized to hold the largest expected ignitable liquid release plus an additional 2 in. (51 mm) of freeboard. Limit the containment footprint to an area no larger than the sprinkler operating area.</td>
</tr>
</tbody>
</table>

Notes:
1. For liquids with flash points at or above 450°F (232°C) in containers larger than 40 gal (150 L), see Section 2.1.3.1.
2. The amount of water that will actually discharge from the sprinklers based on the available water supply, not the theoretical sprinkler discharge.
### Table 3b. Drainage and Containment Requirements for Liquid Storage in Plastic Containers in Cutoff Rooms/Buildings

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Flash Point, Liquid Type (Note 1)</th>
<th>Container Size</th>
<th>Drainage and/or Containment Options and Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic, Glass, or Other Combustible Containers</td>
<td>≥200°F (93°C)</td>
<td>≤6.5 gal (25 L)</td>
<td>None</td>
</tr>
</tbody>
</table>
| | | >6.5 gal (25 L) | 1. Provide containment and drainage arranged to prevent spilled liquid plus actual sprinkler discharge (Note 2) from leaving the room/building of origin for 30 minutes. Arrange the drains to subdivide the room into the smallest practical drainage areas but no larger than 5000 ft² (465 m²). At a minimum, provide 3 in. (7.6 cm) of containment. All containers in the cutoff room are expected to fail.  
Or 2. Provide an FM Approved foam-water sprinkler system or compressed air foam (CAF) system. Provide containment designed to keep spilled liquid plus actual sprinkler discharge (Note 2) in the room-of-origin for 20 minutes. At a minimum, provide 3 in. (7.6 cm) of containment.  
Or 3. For composite IBC storage protected in accordance with Table 13, provide containment and drainage or containment alone arranged to prevent spilled liquid plus actual sprinkler discharge (Note 2) from leaving the room/building of origin for 30 minutes. At a minimum, provide 3 in. (7.6 cm) of containment. |
| | <200°F (93°C) | ≤2 oz (60 ml) | None |
| | | >2 oz (60 ml) | 1. Provide containment and drainage arranged to prevent spilled liquid plus actual sprinkler discharge (Note 2) from leaving the room/building of origin for 30 minutes. Arrange the drains to subdivide the room into the smallest practical drainage areas but no larger than 5000 ft² (465 m²). At a minimum, provide 3 in. (7.6 cm) of containment. All containers in the cutoff room are expected to fail.  
Or 2. Provide an FM Approved foam-water sprinkler system or compressed air foam (CAF) system. Provide containment designed to keep spilled liquid plus actual sprinkler discharge (Note 2) in the room-of-origin for 20 minutes. All containers in the cutoff room are expected to fail. At a minimum, provide 3 in. (7.6 cm) of containment. |
| Water-miscible Group 1, 2, 3 & 4 | ≤1 gal (4 L) | None |
| | >1 gal (L) and ≤60 gal (230 L) | For storage protected using Table 16 or Table 18, provide a minimum of 3 in. (7.6 cm) for containment. For storage protected using Table 12, follow the guidance for containers larger than 60 gal (230 L). |
| | >60 gal (230 L) | 1. Provide containment and drainage arranged to prevent spilled liquid plus actual sprinkler discharge (Note 2) from leaving the room/building of origin for 30 minutes. Arrange the drains to subdivide the room into the smallest practical drainage areas but no larger than 5000 ft² (465 m²). At a minimum, provide 3 in. (7.6 cm) of containment. All containers in the cutoff room are expected to fail.  
Or 2. Provide an FM Approved foam-water sprinkler system or compressed air foam (CAF) system. Provide containment designed to keep spilled liquid plus actual sprinkler discharge (Note 2) in the room-of-origin for 20 minutes. At a minimum, provide 3 in. (7.6 cm) of containment.  
Or 3. For composite IBC storage protected in accordance with Table 13, provide containment and drainage or containment alone arranged to prevent spilled liquid plus actual sprinkler discharge (Note 2) from leaving the room/building of origin for 30 minutes. At a minimum, provide 3 in. (7.6 cm) of containment. |

**Notes:**
1. For liquids with flash points at or above 450°F (232°C) in containers larger than 40 gal (150 L), see Section 2.1.3.1.
2. The amount of water that will actually discharge from the sprinklers based on the available water supply, not the theoretical sprinkler discharge.
2.2.12 Locate and arrange outdoor storage as follows:

A. Locate outdoor ignitable liquid storage that exposes buildings in accordance with Data Sheet 1-22, *Maximum Foreseeable Loss*.

B. Limit non-relieving-style containers larger than 6.5 gal (25 L) in size to one container high for storage located 50 ft (15.2 m) or closer to exposed buildings. Limit relieving-style containers larger than 6.5 gal (25 L) in size to 3 high for storage located 50 ft (15.2 m) or closer to exposed buildings. For storage areas more than 50 ft (15.2 m) from the main building, limit storage heights to those that maintain pile stability.

C. Limit any one dimension of the storage pad/area to 100 ft (30.5 m). Provide curbing/diking around any exterior ignitable liquid storage that is located within 50 ft (15.2 m) of an important building. Provide curbs or dikes for storage pads greater than 50 ft (15.2 m) away from important buildings to control any liquid release. However, if the ground is clearly sloped away from important buildings, utilities, fire protection equipment or other storage pads, dikes are not required for property protection purposes. Arrange curbed/diked areas to permit emergency drainage of impounded liquids.

D. Install a fixed automatic water spray system, arranged to protect the exposed building or facility, in accordance with Section 2.4.1.11 of this data sheet if the recommended space separation distances cannot be provided.

Outdoor storage that is provided with a noncombustible roof for exposure protection may be considered a cutoff room or detached building if the storage arrangements and sprinkler designs are in accordance with Section 2.4, and the construction features of the exposed building are in accordance with Figure 1 and Table 2.

2.3 Occupancy

2.3.1 Housekeeping

2.3.1.1 Establish excellent housekeeping standards for areas storing ignitable liquids. Clean up spills promptly. Keep waste materials in FM Approved oily waste cans. Remove waste daily. Maintain adequate aisles to permit unobstructed movement of personnel and access for firefighting. Do not store other combustibles in the area nor permit any material that might wash into or plug drains. Keep outdoor storage areas clear of grass, weeds, and other combustibles.

2.3.2 Ventilation

Ventilation systems are designed to confine, dilute, and remove the normal amount of flammable vapor released from leaks of ignitable liquids stored in containers. Adequately designed low-level ventilation will reduce the chances of a flammable vapor-air mixture accumulating in the storage area. An adequately designed system will provide a sweeping air movement across all floor areas in the storage building or cutoff room. Designing a ventilation system to remove a large vapor release is outside the scope of this document.

2.3.2.1 Provide continuous low-level ventilation designed in accordance with Table 19. Arrange the system as follows:

A. Arrange mechanical ventilation systems to operate continuously and be monitored so that any loss of ventilation will be detected promptly.

B. Provide a visual or audible ventilation failure alarm at an occupied location to ensure prompt detection.

C. Remove exhaust air through a system of blowers, fans, and duct work terminating out of doors away from air inlets, doorways and other openings.

D. Construct exhaust ducts of noncombustible materials.

E. Provide Class 1 Division 2 rated electrical equipment inside exhaust ducts. Use Table 19 to determine the needed electrical rating for electrical equipment located outside the exhaust ducts but inside the storage room or building. Electrical equipment located outside the exhaust ducts and outside the storage room or building does not need to be hazardous area rated.

F. Run the ducts as directly as possible to the outdoors with a minimum of bends.

G. Protect long runs of ventilation ducts with the potential for accumulation of combustible deposits in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*.

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H. Exhaust systems for small rooms may consist of a fan installed at floor level arranged to exhaust outdoors through the wall.

I. Provide exhaust outlets within 12 in. (0.3 m) of the floor.

J. Provide an FM Approved combustible gas detector arranged to stop recirculation and return to full exhaust when the vapor concentration exceeds 25% of its lower explosive limit (LEL) on ventilation systems that are arranged to recirculate air into the room.

2.3.2.2 Provide make-up air inlets in exterior walls. Locate make-up air inlets remote from exhaust outlets (i.e., on the opposite side of the room) so that air will sweep through the hazardous area. If necessary, provide indirect-fired and properly safeguarded gas or oil make-up air heaters. If make-up air is taken from other facility areas, those areas should be free of ignitable liquids. Install automatically closing fire dampers at make-up air inlet openings in interior fire walls or partitions that have a fire rating equal to that of the walls.

2.3.2.3 Provide a sufficient number of exhaust outlets and make-up air inlets to provide a full and even distribution of ventilation across all floor areas within the storage area. Confirm air movement throughout the area using smoke pencils or other appropriate methods.

2.4 Protection

2.4.1 General

2.4.1.1 Provide automatic sprinkler protection over all areas storing, staging, or used for transporting ignitable liquids. Extend the sprinkler protection to the physical limits of the area. The physical limits are defined by at least one-hour-rated fire walls.

2.4.1.2 Use an FM Approved wet, pre-action, or deluge system. Apply the following:

A. For protection options that specify standard response sprinklers, use either pendant or upright sprinklers.

B. For protection options that specify quick response sprinklers, use only pendent sprinklers unless upright sprinklers are specifically called for in the protection table.

C. For protection options that specify K25EC (360EC) sprinklers, use either pendent or upright sprinklers.

2.4.1.3 Design the sprinkler systems in accordance with the recommendations in this data sheet based on liquid type, container type, storage arrangement, storage height, and building height.

2.4.1.4 Protect staging areas as storage areas. Staged product is any product not actively being moved.

2.4.1.5 Use a deluge sprinkler system in unheated storage areas. If a dry sprinkler system is installed, use a sprinkler design area equal to the cutoff room or building floor area regardless of what is provided in the protection tables. If a pre-action system is used, see 2.4.1.7.2 to determine how to evaluate the system.

2.4.1.6 Install sprinkler systems as follows:

A. Install in accordance Data Sheet 2-0, Installation Guidelines for Automatic Sprinklers. Specific installation guidance provided in this data sheet supersedes other installation data sheets.

B. Provide a maximum of 100 ft² (9 m²) spacing for ceiling sprinklers with a maximum on-line spacing of 10 ft (3 m). A variation of ±1 ft (0.3 m) is permitted on either dimension to avoid building structural elements.

C. Only use the K25EC (360EC) sprinkler (pendent or upright) at the approved maximum spacing and temperature rating. This sprinkler can only be used for protection options that require standard response sprinklers.

D. Do not use ordinary or light hazard, extended coverage sprinklers in liquid storage occupancies.

E. Provide FM Approved fire protection equipment.

F. Provide a minimum discharge pressure of 10 psig (0.7 bar) for all in-rack sprinkler designs.

2.4.1.7 Detector Spacing for Interior Deluge or Pre-action Sprinkler Systems

2.4.1.7.1 Deluge Systems
A. Space pilot sprinklers the same as ceiling sprinklers.

B. Space electric or pneumatic devices under smooth ceilings in accordance with the manufacturer’s specifications, the requirements listed in the Approval Guide for the particular model, and Data Sheet 5-48, Automatic Fire Detection.

2.4.1.7.2 Pre-action Systems

Install electric or pneumatic devices at a spacing of one-half the listed linear detector spacing, or the full sprinkler spacing, whichever is greater. Treat pre-action systems with this detector spacing the same as wet systems for design purposes. If a pre-action system has a detector spacing greater than the above spacing, consider it a dry system for design purposes. Refer to the Approval Guide for maximum allowable spacing.

B. Install pilot sprinklers on the same spacing as the sprinklers. Treat pre-action sprinkler systems that use pilot sprinklers the same as dry systems for design purposes, regardless of detector spacing.

2.4.1.8 Automatic sprinkler protection may be supplemented with one of the following FM Approved fixed special protection systems to limit fire damage in an ignitable liquid storage occupancy, or as an alternative to an emergency drainage system:

A. Foam-water sprinkler system

B. Compressed air foam (CAF) system

Design the special protection systems in accordance with this data sheet, other applicable data sheets, and all of the defined system limitations provided in the Approval Guide. Do not use water mist or gaseous systems in storage occupancies because they have not been shown to be effective against the potential fire scenarios in this type of occupancy.

2.4.1.9 Design and install open-sprinkler (deluge) or closed-sprinkler foam-water sprinkler systems (see Appendix A for definitions) in accordance with the following criteria:

A. Provide an open-sprinkler or closed-sprinkler foam-water sprinkler system when required for a specific storage arrangement or to limit the exposure created by an ignitable liquid fire to surrounding areas when adequate drainage capacity is not available (see Table 3a and 3b).

B. Hydraulically design the system in accordance with a specific foam-water protection table in this data sheet, or to the full water-based sprinkler protection criteria for the storage arrangement, as applicable. In either case, the provided discharge density must be greater than or equal to the required FM Approval density for the foam-sprinkler combination.

C. When a foam-water sprinkler system is used, provide a 20-minute supply of foam concentrate. Base the concentrate supply on the actual sprinkler system discharge (i.e., flow available from the available water supply, not the theoretical design).

D. Design containment for foam-water sprinkler protected areas in accordance with Tables 3a and 3b.

E. Use a compatible foam concentrate for the ignitable liquid being protected. Use FM Approved foam-water sprinkler system components (concentrate, proportioning equipment, tanks, control panels, and sprinklers).

F. Install and maintain the foam-water sprinkler system in accordance with Data Sheet 4-12, Foam-Water Sprinkler Systems.

2.4.1.10 Design and install compressed air foam (CAF) systems in accordance with the following criteria:

A. Install the system in accordance with the manufacturer’s recommendations and its listing in the Approval Guide.

B. Provide a FM Approved fire detection system that is compatible with the CAF system. Provide quick response heat detectors (RTI ≤ 90 ft•s\(^{1/2}\) [50 m•s\(^{1/2}\)]), spaced to provide a response time equivalent to, or earlier than, the installed ceiling sprinklers. If the detection response time cannot be calculated, install the detectors at the same spacing as the ceiling sprinklers.

C. Hydraulically design the sprinkler system in accordance with the appropriate table in this data sheet.
D. Hydraulically design the CAF system in accordance with the manufacturer’s recommendations and its listing in the Approval Guide.

E. Design the foam concentrate supply and system air supply to provide 20 minutes of foam discharge.

F. Provide exterior hose stream demand and water supply duration as recommended in this data sheet.

G. Provide containment and drainage as recommended in this data sheet.

H. Ensure systems are fully acceptance tested when installed. Provide regular maintenance and testing for the system in accordance with Data Sheet 4-12.

2.4.1.11 When water-spray systems are used to provide exposure protection, arrange spray nozzles to ensure complete coverage of the exposed wall. Provide additional nozzles specifically arranged to protect windows. Activate the water-spray system using automatic fire detectors, located to ensure prompt activation of the water-spray system. (See Data Sheet 2-0, Installation Guidelines for Automatic Sprinklers; Data Sheet 4-0, Special Protection Systems; and Data Sheet 4-1N, Fixed Water Spray Systems for Fire Protection.)

2.4.1.12 Provide portable extinguishers in areas (interior and exterior) storing ignitable liquids. Use carbon dioxide, dry chemical, or AFFF type extinguishers. Refer to Data Sheet 4-5, Portable Extinguishers, to determine effective sizes and locations for the extinguishers. Protect extinguishers located outside against freezing.

2.4.1.13 Where small hose (1-1/2 in.) stations are provided in areas storing ignitable liquids, space the hose stations to allow full coverage of the area being protected. Add a water demand of 50 gpm (190 L/min) to the combined sprinkler and hydrant demand for a single hose station (add 100 gpm [380 L/min] for more than one hose station).

2.4.2 Metal Containers (Including IBCs) Larger than 60 gal (230 L)

2.4.2.1 Protect palletized or solid pile storage of metallic IBCs in accordance with Table 4.

2.4.2.2 Protect rack storage of metallic IBCs in accordance with Table 5.

2.4.2.3 Provide a 500 gpm (1900 L/min) hose stream allowance for all cutoff rooms or buildings greater than 2000 ft² (186 m²). Provide a 250 gpm (950 L/min) hose stream allowance for cutoff rooms or buildings less than 2000 ft² (186 m²).

2.4.2.4 Provide a water supply that can deliver the total sprinkler and hose stream demand for a duration of at least one hour.
Table 4. Palletized or Solid-Pile Storage of Ignitable Liquids in Relieving-Style Metal Containers Larger than 60 gal (230 L) (Note 1)

<table>
<thead>
<tr>
<th>Liquid Type/Flash Point (Note 2)</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height (No. of IBCs)</th>
<th>Ceiling Sprinkler Protection</th>
<th>In-Rack Sprinkler Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Response/ Nominal Temperature Rating/ Orientation (Note 3)</td>
<td>K-factor gpm/psi (L/min/bar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K-factor gpm/psi (L/min/bar)</td>
<td>Design, # Sprinklers @ Pressure psi (bar)</td>
</tr>
<tr>
<td>&lt;200°F (93°C)</td>
<td>30 (9.1)</td>
<td>1 high</td>
<td>11.2 (161) (Note 4, 5)</td>
<td>50 @ 7 (0.5)</td>
</tr>
<tr>
<td>≥200°F (93°C)</td>
<td>30 (9.1)</td>
<td>2 high</td>
<td>≥11.2 (161) (Note 4, 5)</td>
<td>50 @ 29 (2.0)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30 @ 51 (3.5)</td>
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<td>14.0 (202)</td>
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<td></td>
<td></td>
<td>50 @ 18 (1.2)</td>
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<td></td>
<td></td>
<td>30 @ 33 (2.3)</td>
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<td></td>
<td>16.8 (235)</td>
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<td></td>
<td></td>
<td>50 @ 13 (0.9)</td>
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<td>30 @ 23 (1.6)</td>
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<td>25.2 (360)</td>
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<td>50 @ 7 (0.5)</td>
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<td>30 @ 10 (0.7)</td>
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<tr>
<td>QR/Ordinary/Any</td>
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<td></td>
<td>25.2EC (360EC)</td>
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<td>26 @ 22 (1.5)</td>
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<td></td>
<td></td>
<td>15 @ 39 (2.7)</td>
</tr>
<tr>
<td>≥200°F (93°C)</td>
<td>30 (9.1)</td>
<td>1 high</td>
<td>11.2 (161) (Note 4, 5)</td>
<td>50 @ 7 (0.5)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>11.2 (161) (Note 4)</td>
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<td></td>
<td></td>
<td></td>
<td>30 @ 29 (2.0)</td>
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<td>14.0 (202)</td>
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<td></td>
<td>30 @ 18 (1.2)</td>
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<td>16.8 (235)</td>
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<td></td>
<td></td>
<td>30 @ 13 (0.9)</td>
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<td></td>
<td>25.2 (360)</td>
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<td></td>
<td></td>
<td>30 @ 7 (0.5)</td>
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<tr>
<td>QR/Ordinary/Any</td>
<td></td>
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<td></td>
<td>25.2EC (360EC)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>15 @ 22 (1.5)</td>
</tr>
</tbody>
</table>

Notes:
1. See Section D.1 for explanation of abbreviations.
2. For liquids with flash points at or above 450°F (232°C) in containers larger than 40 gal (150 L), see Section 2.1.3.1.
3. Buildings or cutoff areas that are equal to or less than the sprinkler operating area can use 165°F (74°C) rated sprinklers in the ceiling sprinkler system.
4. If a foam-water sprinkler system is used, use of K 8.0 (K115) ceiling sprinklers is acceptable as long as an equivalent flow is provided from the K8.0 (K115) sprinkler.
5. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.

Table 5. Rack Storage of Ignitable Liquids in Relieving-Style Metal Containers Larger than 60 gal (230 L) (Note 1)

<table>
<thead>
<tr>
<th>Flash Point OR Liquid Type (Note 2)</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height (No. of IBCs)</th>
<th>Ceiling Sprinkler Protection</th>
<th>In-Rack Sprinkler Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Response/ Nominal Temperature Rating/ Orientation (Note 3)</td>
<td>K-factor gpm/psi (L/min/bar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K-factor gpm/psi (L/min/bar)</td>
<td>Design, # Sprinklers @ Pressure psi (bar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Design, # Sprinklers @ Pressure psi (bar)</td>
<td>Design, # Sprinklers @ Flow gpm (L/min) (see 2.4.1.6F)</td>
</tr>
<tr>
<td>Any</td>
<td>30 (9.1)</td>
<td>3 high</td>
<td>11.2 (161) (Note 4, 5)</td>
<td>50 @ 7 (0.5)</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td>Fig. 3h</td>
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<td></td>
<td>QR/Ordinary</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥8.0 (115)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>12 @ 45 (170)</td>
</tr>
</tbody>
</table>

Notes:
1. See Section D.1 for explanation of abbreviations.
2. For liquids with flash points at or above 450°F (232°C) in containers larger than 40 gal (150 L), see Section 2.1.3.1.
3. Buildings or cutoff areas that are equal to or less than the sprinkler operating area can use 165°F (74°C) rated sprinklers in the ceiling sprinkler system.
4. If a foam-water sprinkler system is used, use of K 8.0 (K115) ceiling sprinklers is acceptable as long as an equivalent flow is provided from the K8.0 (K115) sprinkler.
5. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
2.4.3 Metal Containers Larger than 6.5 gal (25 L) Up to and Including 60 gal (230 L)

2.4.3.1 Protect rack storage in accordance with Table 6.

A. Protection in Table 6 may be used for cutoff rooms or warehouses that are designed to ensure the sprinkler discharge and any ignitable liquid spill are confined to the building/room of fire origin via containment and/or emergency drainage features.

B. Provide 286°F (151°C) rated pendent ceiling sprinklers. Buildings or cutoff areas that are equal to or less than the sprinkler operating area can use 165°F (74°C) rated sprinklers in the ceiling sprinkler system.

C. The figures referred to in the table define the style of rack storage (i.e., single, double, or multiple row) that can be protected.

D. Install in-rack sprinklers in accordance with the figures referred to in the tables.
   1. Locate in-rack sprinklers that are installed in the longitudinal flue space at the junction of transverse flue spaces.
   2. Position in-rack sprinklers at least 1 in. (2.5 cm) in the longitudinal direction from the rack upright structural member, and no further than 6 in. (15 cm) in the longitudinal direction from the edge of the transverse flue.
   3. Locate face sprinklers within 18 in. (46 cm) of the rack face. Locate in-rack sprinkler piping behind horizontal rack members to minimum the potential for damage.
   4. Use FM Approved in-rack sprinklers.

E. Provide at least an 8 ft (2.4 m) aisle between racks.

2.4.3.2 Protect palletized or solid-pile storage in accordance with Table 7. Base the maximum storage height for these containers on the worst-case ignitable liquid stored in the room or building. Apply the following limitations to the protection schemes provided in this table:

A. Provide 286°F (141°C) rated ceiling sprinklers. Buildings or cutoff areas that are equal to or less than the sprinkler operating area can use 165°F (74°C) rated sprinklers in the ceiling sprinkler system. Limit the storage height of liquids with a boiling point below 100°F (38°C) to one container high.

B. Where a relieving-style container is required, provide FM Approved fusible closures on the 2 in. (50.8 mm) and 3/4 in. (19 mm) openings in the top of the container. Purchase the material with the fusible closures installed on the drum before they are delivered. Develop and implement a management control system to ensure the proper plugs are provided in accordance with Recommendation 2.7.5.

C. Palletize relieving-style containers on open deck (i.e., slatted) pallets and store on-end.

D. Design and install foam-water sprinkler systems in accordance with Recommendation 2.4.1.9 of this data sheet.

E. Design foam-water sprinkler systems to deliver foam discharge out of the most remote 4 operating sprinklers within 2 minutes of sprinkler operation. Pre-prime (i.e., pre-fill the sprinkler piping with the correct foam-water mixture) foam-water sprinkler systems that cannot meet the 2-minute delivery time.

2.4.3.3 Provide a 500 gpm (1900 L/min) hose stream allowance for all cutoff rooms or buildings greater than 2000 ft² (186 m²). A 250 gpm (950 L/min) hose stream allowance is acceptable for cutoff rooms or buildings less than or equal to 2000 ft² (186 m²).

2.4.3.4 Provide a water supply that can deliver the total sprinkler and hose stream demand for a duration of at least one hour.
Table 6. Rack Storage of Ignitable Liquids in Metal Containers larger than 6.5 gal (25 L) Up to and Including 60 gal (230 L) with Aisles a Minimum of 8 ft (2.4 m) Wide (Note 1)

<table>
<thead>
<tr>
<th>Flash Point Liquid Type (Note 3)</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Drum Orientation</th>
<th>Protection Type</th>
<th>Ceiling Sprinkler Protection</th>
<th>In-Rack Sprinkler Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any (Note 2)</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>On-End</td>
<td>Water/High</td>
<td>≥11.2 (161) (Note 4, 5)</td>
<td>30 @ 7 (0.5) Fig. 3b, Fig. 3c-1, Fig. 3c-2 QR/Ordinary</td>
</tr>
<tr>
<td>&lt;200°F (60°C)</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>On-End</td>
<td>Water/High</td>
<td>≥11.2 (161) (Note 4, 5)</td>
<td>50 @ 7 (0.5) Fig. 3a, Fig. 3c-1, Fig. 3c-2 QR/Ordinary</td>
</tr>
<tr>
<td>Water-miscible liquids</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>On-End</td>
<td>Water/High</td>
<td>≥11.2 (161) (Note 4, 5)</td>
<td>50 @ 7 (0.5) Fig. 3d QR/Ordinary</td>
</tr>
<tr>
<td>≥200°F (60°C)</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>On-End</td>
<td>Water/High</td>
<td>≥11.2 (161) (Note 4, 5)</td>
<td>50 @ 7 (0.5) Fig. 3e QR/Ordinary</td>
</tr>
</tbody>
</table>

Notes: 1. See Section D.1 for explanation of abbreviations.
2. See Section 2.4.1.9 and Appendix A, Foam-water sprinkler systems.
3. For liquids with flash points at or above 450°F (232°C) in containers larger than 40 gal (150 L), see Section 2.1.3.1.
4. If a foam-water sprinkler system is used, use of K 8.0 (K115) ceiling sprinklers is acceptable as long as an equivalent flow is provided from the K8.0 (K115) sprinkler.
5. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
<table>
<thead>
<tr>
<th>Liquid Type, Flash Point</th>
<th>Maximum Ceiling Height (ft/m)</th>
<th>Drum Orientation</th>
<th>Maximum Height (No. Drums)</th>
<th>Reliefing-style Drum Required (Yes/No)</th>
<th>Protection Type</th>
<th>Response/Nominal Temperature Rating/Orientation</th>
<th>Ceiling Sprinkler Protection</th>
<th>K-factor (gpm/psi) (L/min/bar) (Note 4)</th>
<th>Design, # Sprinklers @ Pressure psi (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any</td>
<td>30 (9.1)</td>
<td>On-End</td>
<td>1</td>
<td>No</td>
<td>Water</td>
<td>SR/High/Any</td>
<td>≥11.2 (161) (Note 5, 6)</td>
<td>50 @ 7 (0.5)</td>
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<td>2</td>
<td>Yes</td>
<td>Water</td>
<td>SR/High/Any</td>
<td>11.2 (161) (Note 5)</td>
<td>50 @ 7 (0.5)</td>
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<td></td>
<td></td>
<td>14.0 (202)</td>
<td>50 @ 18 (1.2)</td>
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<td></td>
<td></td>
<td></td>
<td>16.8 (235)</td>
<td>50 @ 13 (0.9)</td>
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<td>25.2 (360)</td>
<td>50 @ 7 (0.5)</td>
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<td>Foam-Water</td>
<td>SR/High/Any</td>
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<td>30 @ 7 (0.5)</td>
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<td>3</td>
<td>Yes</td>
<td>Foam-Water (Note 4)</td>
<td>SR/High/Any</td>
<td>11.2 (161) (Note 5)</td>
<td>30 @ 16 (1.1)</td>
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<td>14.0 (202)</td>
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<td>≥16.8 (235) (Note 5)</td>
<td>30 @ 7 (0.5)</td>
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<td>4</td>
<td>Yes</td>
<td>Foam-Water</td>
<td>SR/High/Any</td>
<td>11.2 (161) (Note 5)</td>
<td>30 @ 16 (1.1)</td>
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<td>25.2 (360)</td>
<td>30 @ 7 (0.5)</td>
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<tr>
<td>On-Side</td>
<td>1</td>
<td>No (Note 3)</td>
<td>Water</td>
<td>SR/High/Any</td>
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<td>50 @ 7 (0.5)</td>
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<tr>
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<td>3</td>
<td>No (Note 3)</td>
<td>Water</td>
<td>SR/High/Any</td>
<td>11.2 (161) (Note 5)</td>
<td>50 @ 29 (2.0)</td>
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<td>16.8 (235)</td>
<td>50 @ 13 (0.9)</td>
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<td></td>
<td></td>
<td></td>
<td>25.2 (360)</td>
<td>50 @ 7 (0.5)</td>
<td></td>
</tr>
<tr>
<td>≥200°F (80°C) (Note 2)</td>
<td>30 (9.1)</td>
<td>On-End</td>
<td>4</td>
<td>Yes</td>
<td>Water</td>
<td>SR/High/Any</td>
<td>11.2 (161) (Note 5)</td>
<td>50 @ 29 (2.0)</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>14.0 (202)</td>
<td>50 @ 18 (1.2)</td>
<td></td>
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<td></td>
<td></td>
<td>16.8 (235)</td>
<td>50 @ 13 (0.9)</td>
<td></td>
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<td>25.2 (360)</td>
<td>50 @ 7 (0.5)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Side</td>
<td>6</td>
<td>No (Note 3)</td>
<td>Water</td>
<td>SR/High/Any</td>
<td>11.2 (161) (Note 5)</td>
<td>50 @ 29 (2.0)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>14.0 (202)</td>
<td>50 @ 18 (1.2)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>16.8 (235)</td>
<td>50 @ 13 (0.9)</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25.2 (360)</td>
<td>50 @ 7 (0.5)</td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. See Section D.1 for explanation of abbreviations.
2. For liquids with flash points at or above 450°F (232°C) in containers larger than 40 gal (150 L), see Section 2.1.3.1.
3. Never use a relieving-style drum when drums are stored on side. This storage arrangement will allow relieving-style drums to empty if the plugs open.
4. Unsaturated polyester resin (UPR) mixtures with 50% or less styrene can be protected palletized to 3 relieving-style drums high without a foam-water sprinkler system.
5. If a foam-water sprinkler system is used, use of K 8.0 (K115) ceiling sprinklers is acceptable as long as an equivalent flow is provided from the K8.0 (K115) sprinkler.
6. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
2.4.4 Metal Containers of 6.5 gal (25 L) or Less

Protecting any size metal container filled with an ignitable liquid requires adequate water to cool the container to prevent its violent rupture or the creation of a jet fire. Palletized storage arrangements significantly limit the ability of ceiling sprinkler discharge to provide cooling to containers that are at the bottom of the storage array. Full-scale fire testing has shown that standard response, small orifice sprinklers (i.e., smaller than K11.2 [K160]) cannot provide adequate protection for palletized arrays of small metal containers regardless of the liquid’s flash point.

2.4.4.1 Protect rack storage in accordance with Table 8 or 9. Table 9 can only be applied to the storage of relieving-style metal containers (see Appendix A for definition) and ignitable liquids with a boiling point above 100°F (38°C).

2.4.4.2 Protect palletized or solid-pile storage in accordance with Table 9 or 10. Table 9 can only be applied to the storage of relieving-style metal containers (see Appendix A for definition) and ignitable liquids with a boiling point above 100°F (38°C).

2.4.4.3 Protect shelf storage in accordance with Table 11. Limit shelves to no more than a 2 ft (0.6 m) deep (dimension from aisle face to back of shelf) and noncombustible construction. Separate back-to-back shelves with a noncombustible partition. Treat shelves lacking this partition like a single-row rack.

2.4.4.4 Provide a 500 gpm (1900 L/min) hose stream allowance for all cutoff rooms or buildings larger than 2000 ft² (186 m²). A 250 gpm (950 L/min) hose stream allowance is acceptable for cutoff rooms or buildings smaller than 2000 ft² (186 m²).

2.4.4.5 Provide a water supply that can deliver the total sprinkler and hose stream demand for a duration of at least one hour.
Table 8. Rack Storage of Ignitable Liquid in Metal Containers Up to and Including 6.5 gal (25 L) with Aisles a Minimum of 8 ft (2.4 m) Wide (Note 1)

<table>
<thead>
<tr>
<th>Liquid Type, Flash Point</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Packaging Type</th>
<th>Ceiling Sprinkler Protection</th>
<th>In-Rack Sprinkler Protection</th>
<th>Note 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Response/Nominal Temperature Rating/Orientation</td>
<td>K-factor gpm/psi$^{1/2}$ (L/min/bar$^{1/2}$)</td>
<td># Sprinklers @ Pressure psi (bar)</td>
</tr>
<tr>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Uncarton and/or Cartoned</td>
<td>SR/Ordinary /Any</td>
<td>30 @ 7 (0.5)</td>
<td>Scheme A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Figs. 4a, 4b, 4c, 4d</td>
</tr>
<tr>
<td>Any</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>Uncarton and/or Cartoned</td>
<td>SR/Ordinary /Any</td>
<td>11.2 (161) (Note 3)</td>
<td>14.0 (202)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.8 (235)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25.2 (360)</td>
</tr>
<tr>
<td>Cartoned Only</td>
<td>SR/Ordinary /Any</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30 @ 7 (0.5)</td>
</tr>
<tr>
<td></td>
<td>SR/Ordinary /Any</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30 @ 7 (0.5)</td>
</tr>
<tr>
<td></td>
<td>QR/Ordinary /Any</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30 @ 7 (0.5)</td>
</tr>
<tr>
<td>Water- miscible</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>Uncarton and/or Cartoned</td>
<td>SR/Ordinary /Any</td>
<td>11.2 (161) (Note 3)</td>
<td>14.0 (202)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.8 (235)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25.2 (360)</td>
</tr>
<tr>
<td></td>
<td>QR/Ordinary /Any</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30 @ 7 (0.5)</td>
</tr>
</tbody>
</table>

Notes: 1. See Section D.1 for explanation of abbreviations.
2. Base the in-rack sprinkler water demand on the simultaneous operation of the most hydraulically remote sprinklers as follows:
   a. Eight (8) sprinklers where only one level of in-rack sprinklers is installed
   b. Twelve (12) sprinklers (six on each two top levels) where two levels of in-rack sprinklers are installed
   c. Eighteen (18) sprinklers (six on top three levels) where more than two levels of in-rack sprinklers are installed
   d. The in-rack end head pressure as provided in Table 8
3. If a foam-water sprinkler system is used, use of K8.0 (K115) ceiling sprinklers is acceptable as long as an equivalent flow is provided from the K8.0 (K115) sprinkler.
4. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
<table>
<thead>
<tr>
<th>Storage Arrangement</th>
<th>Minimum Aisle Width ft (m)</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Packaging Type</th>
<th>Ceiling Sprinkler Protection</th>
<th>In-Rack Sprinkler Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Response/Nominal Temperature Rating/ Sprinkler Orientation</td>
<td>K-factor gpm/psi(^{1/2}) (L/min/bar(^{1/2}))</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Design, # of Sprinklers @ Pressure psi (bar)</td>
<td>(see figure indicated)</td>
</tr>
<tr>
<td>Single &amp; Double Row Racks</td>
<td>8 (2.4)</td>
<td>33 (10)</td>
<td>25 (7.6)</td>
<td>Uncartoned and/or Cartoned</td>
<td>QR/Ordinary/ Pendant</td>
<td>14.0 (202) 12 @ 75 (5.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cartoned Only</td>
<td>QR/Ordinary/ Pendant</td>
<td>14.0 (202) 12 @ 50 (3.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple Row Racks</td>
<td>None</td>
<td>33 (10)</td>
<td>25 (7.6)</td>
<td>Uncartoned and/or Cartoned</td>
<td>QR/Ordinary/ Pendant</td>
<td>14.0 (202) 12 @ 75 (5.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paletized DNA</td>
<td>33 (10)</td>
<td>12 (3.7)</td>
<td></td>
<td>Uncartoned and/or Cartoned</td>
<td>QR/Ordinary/ Pendant</td>
<td>14.0 (202) 12 @ 75 (5.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. See Section D.1 for explanation of abbreviations.
2. Base the in-rack sprinkler water demand on the simultaneous operation of the most hydraulically remote sprinklers as follows:
   a. Eight (8) sprinklers where only one level of in-rack sprinklers is installed
   b. Twelve (12) sprinklers (six on each two top levels) where two levels of in-rack sprinklers are installed
   c. Eighteen (18) sprinklers (six on top three levels) where more than two levels of in-rack sprinklers are installed
### Table 10. Palletized/Solid-Pile Storage of Liquids In Metal Containers Up to and Including 6.5 gal (25 L) (Note 1)

<table>
<thead>
<tr>
<th>Liquid Type, Flash Point</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Packaging Type</th>
<th>Ceiling Sprinkler Protection</th>
<th>K-factor gpm/psi^{1/2} (L/min/bar^{1/2})</th>
<th>Design, # of Sprinklers @ Pressure psi (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any</td>
<td>30 (9.1)</td>
<td>5 (1.5)</td>
<td>Uncartoned and/or Cartoned</td>
<td>QR/Ordinary/Any</td>
<td>14.0 (202)</td>
<td>50 @ 18 (1.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.8 (235)</td>
<td>50 @ 13 (0.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥22.4 (320)</td>
<td>50 @ 7 (0.5)</td>
</tr>
<tr>
<td>Cartoned Only</td>
<td>12 (3.7)</td>
<td></td>
<td></td>
<td>SR/Ordinary/Any</td>
<td>11.2 (161)</td>
<td>50 @ 29 (2.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14.0 (202)</td>
<td>50 @ 18 (1.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.8 (235)</td>
<td>50 @ 13 (0.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25.2 (360)</td>
<td>50 @ 7 (0.5)</td>
</tr>
<tr>
<td>SR/High/Any</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25.2EC (360EC)</td>
<td>26 @ 22 (1.5)</td>
</tr>
</tbody>
</table>

Notes:
1. See Section D.1 for explanation of abbreviations.
2. If a foam-water sprinkler system is used, use of K 8.0 (K115) ceiling sprinklers is acceptable as long as an equivalent flow is provided from the K8.0 (K115) sprinkler.

### Table 11. Shelf Storage of Liquids in Metal Containers Up to and Including 6.5 gal (25 L) (Note 1)

<table>
<thead>
<tr>
<th>Liquid Type, Flash Point</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Ceiling Sprinkler Protection</th>
<th>K-factor gpm/psi^{1/2} (L/min/bar^{1/2})</th>
<th>Design, # of Sprinklers @ Pressure psi (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 200°F (93°C)</td>
<td>30 (9.1)</td>
<td>7 (2.1)</td>
<td>SR/Ordinary/Any</td>
<td>≥11.2 (161)</td>
<td>50 @ 7 (0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>QR/Ordinary/Any</td>
<td>25.2EC (360EC)</td>
<td>26 @ 7 (0.5)</td>
</tr>
<tr>
<td>≥200°F (93°C) or water- miscible</td>
<td>30 (9.1)</td>
<td>15 (4.6)</td>
<td>SR/Ordinary/Any</td>
<td>≥11.2 (161)</td>
<td>30 @ 7 (0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>QR/Ordinary/Any</td>
<td>25.2EC (360EC)</td>
<td>15 @ 7 (0.5)</td>
</tr>
</tbody>
</table>

Notes:
1. See Section D.1 for explanation of abbreviations.
2. If a foam-water sprinkler system is used, use of K 8.0 (K115) ceiling sprinklers is acceptable as long as an equivalent flow is provided from the K8.0 (K115) sprinkler.
3. The K19.8 (K280) sprinkler is not acceptable for use in this protection table.
2.4.5 Protection of Plastic, Composite (Plastic-Metal), or Other Combustible Containers: General

Proven protection schemes for liquid-packaging combinations that are tied only to Table 12 are not currently available. The recommended protection will not prevent the consumption of all of the liquid stored in the cutoff room or building, but it may prevent structural failure of the roof and walls by cooling the structures. For large containers, the quantity of liquid in a single container greatly increases the potential for a spill fire that will activate all of the sprinklers in the cutoff room or building. The addition of a foam-water sprinkler system has not been shown to improve any of the protection line items tied only to Table 12.

2.4.5.1 Protect storage of all ignitable liquids in plastic, composite (plastic-metal), glass, or other combustible packing in accordance with Table 12.

2.4.5.2 Provide a 500 gpm (1900 L/min) hose stream allowance.

2.4.5.3 Provide a water supply that can deliver the total sprinkler and hose stream demand for a duration of at least one hour.

2.4.5.4 Protect palletized storage arrays of empty composite IBCs in buildings up to 30 ft (9 m) high as follows:

   A. Protect up to 3 high composite IBCs with plastic pallets using K14.0 (K200), quick response, pendant sprinklers arranged to provide a discharge pressure of 32 psi (2.2 bar) over 12 sprinklers.

   B. Protect up to 3 high composite IBCs with wooden or steel pallets using K14.0 (K200), quick response, pendant sprinklers arranged to provide a discharge pressure of 18 psi (1.2 bar) over 12 sprinklers.
### Table 12. Fire Protection Criteria for Ignitable Liquids in Plastic or Glass Containers

<table>
<thead>
<tr>
<th>Liquid Type, Flash Point</th>
<th>Container Size gal (L)</th>
<th>Storage Arrangement</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Ceiling Sprinkler Protection</th>
<th>Ceiling Sprinkler System Type</th>
<th>Design, # of Sprinklers @ Pressure psi (bar)</th>
<th>K-factor gpm psi^{1/2} (L/min/bar^{1/2}) (Note 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;200°F (93°C)</td>
<td>&gt;1 (4)</td>
<td>Palletized</td>
<td>30 (9.1)</td>
<td>5 (1.5)</td>
<td>Any</td>
<td>SR or QR/Ordinary/Any</td>
<td>Entire Room @ 75 (5.2)</td>
<td>11.2 (161)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 48 (3.3)</td>
<td>14.0 (202)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 33 (2.3)</td>
<td>16.8 (235)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 19 (1.3)</td>
<td>22.4 (320)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Deluge or Foam-Water</td>
<td>Entire Room @ 15 (1.0)</td>
<td>25.2 (360)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SR or QR/Ordinary/Any</td>
<td>Entire Room @ 50 (3.5)</td>
<td>11.2 (161)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 32 (2.2)</td>
<td>14.0 (202)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 22 (1.5)</td>
<td>16.8 (235)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 12 (0.8)</td>
<td>22.4 (320)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 10 (0.7)</td>
<td>25.2 (360)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rack Storage</td>
<td>Use Section 2.4.7.1 and Table 14. If liquid-package combination is not covered by Table 14, use criteria for palletized storage above.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>≤1 (4)</td>
<td></td>
<td>30 (9.1)</td>
<td>5 (1.5)</td>
<td>Any</td>
<td>SR or QR/Ordinary/Any</td>
<td>Entire Room @ 75 (5.2)</td>
<td>11.2 (161)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 48 (3.3)</td>
<td>14.0 (202)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 33 (2.3)</td>
<td>16.8 (235)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Deluge or Foam-Water</td>
<td>Entire Room @ 19 (1.3)</td>
<td>22.4 (320)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SR or QR/Ordinary/Any</td>
<td>Entire Room @ 15 (1.0)</td>
<td>25.2 (360)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 50 (3.5)</td>
<td>11.2 (161)</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>Entire Room @ 32 (2.2)</td>
<td>14.0 (202)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 22 (1.5)</td>
<td>16.8 (235)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 12 (0.8)</td>
<td>22.4 (320)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 10 (0.7)</td>
<td>25.2 (360)</td>
</tr>
<tr>
<td>Water-miscible liquids</td>
<td>&gt;6.5 (25)</td>
<td>Palletized</td>
<td>30 (9.1)</td>
<td>5 (1.5)</td>
<td>Any</td>
<td>SR or QR/Ordinary/Any</td>
<td>Entire Room @ 30 (2.0)</td>
<td>11.2 (161)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 19 (1.3)</td>
<td>14.0 (202)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 13 (0.9)</td>
<td>16.8 (235)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥22.4 (320)</td>
<td>Entire Room @ 7 (0.5)</td>
<td>25.2 (360)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rack Storage</td>
<td>Use Section 2.4.6 and Table 13, or Section 2.4.7.3 and Table 16, for Group 1, 2, 3, and 4 water-miscible liquids (defined in Section 3.1.1). If liquid-package combination is not covered by Table 13, use criteria for palletized storage above.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≤6.5 (25)</td>
<td>Use Section 2.4.7.3 and Tables 16 and 18 for Group 1, 2, 3, and 4 water-miscible liquids (defined in Section 3.1.1). Protect water-miscible liquids that are not included in one of the groups or Tables 16 and 18 using the criteria provided for water-miscible liquids in containers &gt;6.5 gal (25 L) in this table.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥200°F (93°C)</td>
<td>&gt;6.5 (25)</td>
<td>Palletized</td>
<td>30 (9.1)</td>
<td>5 (1.5)</td>
<td>Any</td>
<td>SR or QR/Ordinary/Any</td>
<td>Entire Room @ 30 (2.0)</td>
<td>11.2 (161)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 19 (1.3)</td>
<td>14.0 (202)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entire Room @ 13 (0.9)</td>
<td>16.8 (235)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥22.4 (320)</td>
<td>Entire Room @ 7 (0.5)</td>
<td>25.2 (360)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rack Storage</td>
<td>Use Section 2.4.6 and Table 13, if liquid-package combination is not covered by Table 13, use criteria for palletized storage above.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≤6.5 (25)</td>
<td>Use Section 2.4.7.2 and Tables 15 and 17. If liquid-package combination is not covered by Tables 15 or 17, use criteria for containers &gt;6.5 gal (25 L) in this table.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;450°F (232°C)</td>
<td>≥40 (140)</td>
<td>See Section 2.1.3.1 to define fire protection.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
2.4.6 Composite (blow molded bottle in a wire cage on a wood or steel pallet) IBC Storage of Liquids with a Flash Point At or Above 200°F (93°C) or Alcohol in Racks

2.4.6.1 Use Table 13 to protect rack storage of liquids with a flash point at or above 200°F (93°C) or alcohol (isopropyl alcohol, ethyl alcohol, methyl alcohol) in composite IBCs consisting of a blow molded bottle in a wire cage on a wood or steel pallet. Protect all tiers of the rack with the same level of fire protection.

2.4.6.2 Limit IBC storage to the first tier of the rack. Upper tiers may be used for storage of other liquid-packaging combinations that are 60 gal (230 L) or less in size and that can be protected by the provided level of protection.

2.4.6.3 Arrange the room to ensure all storage is kept in the racks and not staged or stored on the floor. The provided ceiling protection will not prevent failure of any IBC not stored in the racks and will only provide limited protection for large pool fires.

<table>
<thead>
<tr>
<th>Table 13. Rack Storage of Liquids in Composite IBCs (blow molded bottle in a wire cage on a wood or steel pallet)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liquid Type, Flash Point</strong></td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td>≥200°F (93°C) or Alcohol</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
2. In cutoff rooms where on-floor storage is impossible, i.e., only rack storage and transport aisles, the ceiling sprinkler operating area can be reduced to 20 sprinklers for non-EC sprinklers and 10 sprinklers for the K25.2 EC (360 EC) sprinkler.

2.4.7 Plastic, Glass, or Other Combustible/Brittle Containers Up to and Including 60 gal (230 L)

2.4.7.1 Protect storage of non-water-miscible liquids with flash points below 200°F (93°C) as follows:

A. Provide sprinkler protection according to Table 12 or 14, based on container size, storage arrangement, roof/ceiling height, and storage height.

B. When needed, provide foam-water protection in accordance with this data sheet and Data Sheet 4-12.

C. Provide a 500 gpm (1900 L/min) hose stream allowance for all cutoff rooms or buildings larger than 2000 ft² (186 m²). A 250 gpm (950 L/min) hose stream allowance is acceptable for cutoff rooms or buildings smaller than 2000 ft² (186 m²).

D. Provide a water supply that can deliver the total sprinkler and hose stream demand for a duration of at least one hour.

2.4.7.2 Protect storage of liquids with flash points at or above 200°F (93°C) as follows:

A. Provide sprinkler protection per Tables 15 or 17, as applicable, based on storage arrangement, roof/ceiling height, and storage height.

B. Provide a 500 gpm (1900 L/min) hose stream allowance for all cutoff rooms or buildings larger than 2000 ft² (186 m²). A 250 gpm (950 L/min) hose stream allowance is acceptable for cutoff rooms or buildings smaller than 2000 ft² (186 m²).

C. Provide a water supply that can deliver the total sprinkler and hose stream demand for a duration of at least one hour.

2.4.7.3 Protect storage of Group 1, 2, 3, and 4 water-miscible liquids as follows:

A. Provide sprinkler protection per Tables 16 or 18, as applicable, based on storage arrangement, roof/ceiling height, and storage height.
B. Protect Group 5 water-miscible liquids as nonignitable liquids. Use Data Sheet 8-1, Commodity Classification, to determine the appropriate commodity classification.

C. Provide a 500 gpm (1900 L/min) hose stream allowance for all cutoff rooms or buildings larger than 2000 ft² (186 m²). A 250 gpm (950 L/min) hose stream allowance is acceptable for cutoff rooms or buildings smaller than 2000 ft² (186 m²).

D. Provide a water supply that can deliver the total sprinkler and hose stream demand for a duration of at least one hour.
Table 14. Rack Storage of Liquids in Plastic or Glass Containers with Flash Points Below 200°F (93°C) (Note 1)

<table>
<thead>
<tr>
<th>Liquid Type, Flash Point</th>
<th>Container Size</th>
<th>Packaging Type</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Minimum Aisle Width ft (m)</th>
<th>Rack Width ft (m)</th>
<th>Protection Type</th>
<th>Ceiling Sprinkler Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤200°F (93°C) ≤0.5 oz (15 ml)</td>
<td>Cartoned</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>8 (2.4)</td>
<td>≤9 (2.7)</td>
<td>Water</td>
<td>SR/Ordinary/ Any</td>
<td>≤11.2 (161)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Scheme C</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td>QR/Ordinary/ Pendent</td>
<td>14.0 (202)</td>
<td>12 @ 50 (3.5)</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>QR/Ordinary/ Pendent</td>
<td>16.8 (235)</td>
<td>12 @ 35 (2.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>QR/Ordinary/ Pendent</td>
<td>22.4 (310)</td>
<td>12 @ 35 (2.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>QR/Ordinary/ Pendent</td>
<td>25.2 (360)</td>
<td>12 @ 35 (2.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartoned ≤2 oz (60 ml)</td>
<td>Cartoned</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>4 (1.2)</td>
<td>Any</td>
<td>Water</td>
<td>Any</td>
<td>Any</td>
</tr>
<tr>
<td>≤1 gal (4 L)</td>
<td>Cartoned</td>
<td>35 (10.6)</td>
<td>20 (6)</td>
<td>8 (2.4)</td>
<td>≤9 (2.7)</td>
<td>Foam-Water</td>
<td>SR/Ordinary/ Any</td>
<td>≤11.2 (161)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Scheme D</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. See Section D.1 for explanation of abbreviations. See Section D.2.2 for fire protection schemes.
2. If a foam-water sprinkler system is used, use of K 8.0 (K115) ceiling sprinklers is acceptable as long as an equivalent flow is provided from the K8.0 (K115) sprinkler.
3. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
Table 15. Rack Storage of Liquids in Plastic or Glass Containers with Flash Points At or Above 200°F (93°C) (Note 1)

<table>
<thead>
<tr>
<th>Flash Point</th>
<th>Container Size</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Packaging Type</th>
<th>Minimum Aisle Width ft (m)</th>
<th>Rack Width ft (m)</th>
<th>Ceiling Sprinkler Protection</th>
<th>K-factor gpm/psi(^{1/2}) (L/min/bar(^{1/2}))</th>
<th>Design, # of Sprinklers @ Pressure psi (bar)</th>
<th>In-Rack Sprinkler Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥200°F (93°C) ≤8.5 gal (25 L)</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>Uncarton and/or Cartoned</td>
<td>4 (1.2)</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Scheme A</td>
<td>Scheme A</td>
</tr>
<tr>
<td>≥450°F (232°C) ≤8.5 gal (25 L)</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>Uncarton and/or Cartoned</td>
<td>4 (1.2)</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Scheme A</td>
<td>Scheme A</td>
</tr>
<tr>
<td>40 (12.1)</td>
<td>35 (10.7)</td>
<td>Uncarton and/or Cartoned</td>
<td>4 (1.2)</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Scheme A</td>
<td>Scheme A</td>
</tr>
<tr>
<td>Cartoned Only</td>
<td>8 (2.4)</td>
<td>≤9 (2.7)</td>
<td>SR/Ordinary/Any</td>
<td>≥11.2 (161) (Note 2)</td>
<td>20 @ 7 (0.5)</td>
<td>Scheme B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QR/Ordinary/Any</td>
<td>25.2EC (360EC)</td>
<td>11 @ 7 (0.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>Uncarton and/or Cartoned</td>
<td>8 (2.4)</td>
<td>≤9 (2.7)</td>
<td>SR/Ordinary/Any</td>
<td>≥11.2 (161) (Note 2)</td>
<td>20 @ 7 (0.5)</td>
<td>Scheme C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QR/Ordinary/Any</td>
<td>25.2EC (360EC)</td>
<td>11 @ 7 (0.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartoned Only</td>
<td>4 (1.2)</td>
<td>≤9 (2.7)</td>
<td>SR/Ordinary/Pendent</td>
<td>≥14.0 (202) (Note 2)</td>
<td>12 @ 75 (5.2)</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 (2.4)</td>
<td>≤9 (2.7)</td>
<td>QR/Ordinary/Any</td>
<td>≥14.0 (202) (Note 2)</td>
<td>12 @ 75 (5.2)</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 (4.6)</td>
<td>Uncarton and/or Cartoned</td>
<td>4 (1.2)</td>
<td>≤9 (2.7)</td>
<td>SR/Ordinary/Any</td>
<td>≥11.2 (161) (Note 2)</td>
<td>20 @ 7 (0.5)</td>
<td>Scheme B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QR/Ordinary/Any</td>
<td>25.2EC (360EC)</td>
<td>11 @ 7 (0.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartoned Only</td>
<td>4 (1.2)</td>
<td>≤9 (2.7)</td>
<td>QR/Ordinary/Pendent</td>
<td>≥14.0 (202) (Note 2)</td>
<td>12 @ 50 (3.5)</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48 oz (1.4 l)</td>
<td>40 (12.1)</td>
<td>35 (10.7)</td>
<td>Cartoned Only</td>
<td>4 (1.2)</td>
<td>≤9 (2.7)</td>
<td>QR/Ordinary/Pendent</td>
<td>25.2 (363)</td>
<td>12 @ 40 (2.8)</td>
<td>Scheme C</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. See Section D.1 for explanation of abbreviations. See Section D.2.2 for fire protection schemes.
2. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
Table 16. Rack Storage of Group 1, 2, 3, and 4 Water-Miscible Liquids in Plastic or Glass Containers (Note 1)

<table>
<thead>
<tr>
<th>Water-miscible Group (see Section 3.1.1)</th>
<th>Container Size</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Packaging Type</th>
<th>Minimum Aisle Width ft (m)</th>
<th>Rack Type</th>
<th>Ceiling Sprinkler Protection</th>
<th>In-Rack Sprinkler Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1, 2, 3 &amp; 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K-factor gpm/psi(^{1/2}) (L/min/bar(^{1/2}))</td>
<td>Design, # of Sprinklers @ Pressure psi (bar)</td>
</tr>
<tr>
<td>&gt;6.5 gal (25 L) and ≤60 gal (230 L)</td>
<td>45 (13.7)</td>
<td>30 (9.1)</td>
<td>8 (2.4)</td>
<td>Uncarton and/or Cartoned</td>
<td></td>
<td></td>
<td>SRR / DRR</td>
<td>11.2 (161) / 10 @ 7 (0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>25.2EC (360EC) / 15 @ 10 (0.7)</td>
</tr>
<tr>
<td>≤6.5 gal (25 L)</td>
<td>35 (11)</td>
<td>10 (3)</td>
<td>8 (2.4)</td>
<td>Uncarton and/or Cartoned</td>
<td></td>
<td></td>
<td>SRR / Ordinary / Any</td>
<td>11.2 (161) / 30 @ 13 (0.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>14.0 (202) / 30 @ 8 (0.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥16.8 (235) (Note 2)</td>
<td>30 @ 7 (0.5)</td>
</tr>
<tr>
<td>≤1 gal (4 L)</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>Carton Only</td>
<td>Any</td>
<td>Any</td>
<td></td>
<td>Scheme A</td>
<td></td>
</tr>
<tr>
<td>≤6 oz (180 ml)</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>8 (2.4)</td>
<td>Carton Only</td>
<td>Any</td>
<td></td>
<td>QR / Ordinary / Pendant</td>
<td>14.0 (202) / 12 @ 50 (3.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SR / Ordinary / Any</td>
<td>11.2 (161) / 20 @ 29 (2.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>14.0 (202) / 20 @ 25 (1.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>16.8 (235) / 25.2 (360)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>20 @ 7 (0.5)</td>
</tr>
<tr>
<td>≤1 gal (4 L)</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>Carton only</td>
<td>Any</td>
<td>Any</td>
<td></td>
<td>Scheme A</td>
<td></td>
</tr>
<tr>
<td>≤6 oz (180 ml)</td>
<td>40 (12)</td>
<td>35 (10.6)</td>
<td>8 (2.4)</td>
<td>Carton Only</td>
<td>Any</td>
<td></td>
<td>QR / Ordinary / Pendant</td>
<td>14.0 (202) / 12 @ 75 (5.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SR / Ordinary / Any</td>
<td>16.8 (235) / 22.4 (310)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>20 @ 7 (0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>25.2EC (360EC) / 10 @ 7 (0.5)</td>
</tr>
<tr>
<td>Group 2</td>
<td>≤1 gal (4 L)</td>
<td>Unlimited</td>
<td>Carton only</td>
<td>Any</td>
<td>Any</td>
<td></td>
<td>Scheme A</td>
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<tr>
<td>Group 3</td>
<td>≤6 oz (180 ml)</td>
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<td></td>
<td>Scheme A</td>
<td></td>
</tr>
<tr>
<td>≤1 gal (4 L)</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>8 (2.4)</td>
<td>Carton Only</td>
<td>Any</td>
<td></td>
<td>QR / Ordinary / Pendant</td>
<td>14.0 (202) / 12 @ 50 (3.4)</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>SR / Ordinary / Any</td>
<td>11.2 (161) / 20 @ 29 (2.0)</td>
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<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>14.0 (202) / 20 @ 18 (1.2)</td>
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<td></td>
<td>QR / Ordinary / Any</td>
<td>16.8 (235) / 25.2 (360)</td>
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<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>20 @ 7 (0.5)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>QR / Ordinary / Any</td>
<td>25.2EC (360EC) / 10 @ 7 (0.5)</td>
</tr>
</tbody>
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(Note 1)
<table>
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<tr>
<th>Water-miscible Group (see Section 3.1.1)</th>
<th>Container Size</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Packaging Type</th>
<th>Rack Type</th>
<th>Minimum Aisle Width ft (m)</th>
<th>Design, # of Sprinklers @ Pressure psi (bar)</th>
<th>Layout</th>
<th>Response/ Nominal Temperature Rating</th>
<th>K-factor gpm/psi(^{1/2}) (L/min/bar(^{1/2}))</th>
<th>Design, Flow gpm (L/min) (see 2.4.1.6F)</th>
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</thead>
<tbody>
<tr>
<td><strong>Group 3</strong></td>
<td>≤59 oz (1.75 L)</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>Cartoned</td>
<td>Any</td>
<td>4 (1.2)</td>
<td>Any</td>
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<td></td>
<td></td>
<td>Scheme E</td>
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<td>≥11.2 (160)</td>
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<td></td>
<td>Any</td>
<td>14.0 (202)</td>
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<td>Any</td>
<td>16.8 (235)</td>
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<td>Any</td>
<td>25.2 (360)</td>
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<td></td>
<td>Any</td>
<td>25.2EC (360EC)</td>
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<tr>
<td><strong>Group 4</strong></td>
<td>≤6.5 gal (25 L)</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>Cartoned only</td>
<td>Any</td>
<td>8 (2.4)</td>
<td>Any</td>
<td></td>
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<td></td>
<td>Scheme A</td>
</tr>
<tr>
<td></td>
<td>≤1 gal (4 L)</td>
<td>30 (9.1)</td>
<td>25 (7.6)</td>
<td>Cartoned Only</td>
<td>8 (2.4)</td>
<td>DRR</td>
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<td></td>
<td>Any</td>
</tr>
</tbody>
</table>

Note: 1. See Section D.1 for explanation of abbreviations. See Section D.2.2 for fire protection schemes.
2. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
3. Base the in-rack sprinkler water demand on the simultaneous operation of the most hydraulically remote sprinklers as follows:
   a) Eight (8) sprinklers where only one level of in-rack sprinklers is installed
   b) Fourteen (14) sprinklers (seven on each two top levels) where two levels of in-rack sprinklers are installed
   c) Eighteen (18) sprinklers (six on top three levels) where more than two levels of in-rack sprinklers are installed
   d) The in-rack discharge pressure as provided in Table 16.
4. Base the in-rack sprinkler water demand on the simultaneous operation of the most hydraulically remote sprinklers as follows:
   a) Eight (8) sprinklers where only one level of in-rack sprinklers is installed
   b) Fourteen (14) sprinklers (seven on each two top levels) where two levels of in-rack sprinklers are installed
   c) Eighteen (18) sprinklers (six on top three levels) where more than two levels of in-rack sprinklers are installed
   d) The in-rack discharge pressure as provided in Table 16.
4. Where the figures referred to are part of the fire protection for Scheme C, only use the figures; do not apply the entire fire protection scheme.
Table 17. Palletized/Solid Pile Storage of Liquids with Closed-Cup Flash Points At or Above 200°F (93°C) in Plastic Containers (Note 1)

<table>
<thead>
<tr>
<th>Liquid Type, Flash Point</th>
<th>Container Size</th>
<th>Packaging Type</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Ceiling Sprinkler Protection</th>
<th>Response / Nominal Temperature Rating/ Orientation</th>
<th>K-factor gpm/psi(^{1/2}) (L/min/bar(^{1/2}))</th>
<th>Design, # of Sprinklers @ Pressure psi (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥200°F (93°C) ≤6.5 gal (25 L) Cartoned Only</td>
<td>40 (12.1)</td>
<td>15 (4.6)</td>
<td>QR/Ordinary/Pendant</td>
<td>14.0 (202)</td>
<td>12 @ 75 (5.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 (9.1)</td>
<td>15 (4.6)</td>
<td>QR/Ordinary/Pendant</td>
<td>14.0 (202)</td>
<td>12 @ 50 (3.5)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.0 (202)</td>
<td>25 @ 39 (2.7)</td>
<td>SR/Ordinary/Any</td>
<td>11.2 (161)</td>
<td>25 @ 29 (2.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.8 (236)</td>
<td>25 @ 23 (1.6)</td>
<td>25.2 (360)</td>
<td>25 @ 10 (0.7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.2 (161)</td>
<td>25 @ 23 (1.6)</td>
<td>SR/Ordinary/Any</td>
<td>11.2 (161)</td>
<td>20 @ 51 (3.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.0 (202)</td>
<td>20 @ 33 (2.3)</td>
<td>16.8 (236)</td>
<td>20 @ 23 (1.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.2 (360)</td>
<td>20 @ 10 (0.7)</td>
<td>QR/Ordinary/Any</td>
<td>25.2EC (360EC)</td>
<td>13 @ 22 (1.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 (1.5)</td>
<td>QR/Ordinary/Pendant</td>
<td>14.0 (202)</td>
<td>12 @ 50 (3.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

≥450°F (233°C) ≤6.5 gal (25 L) Uncarton and/or Cartoned | 40 (12.1) | 15 (4.6) | QR/Ordinary/Pendant | 14.0 (202) | 12 @ 75 (5.2) |
| 30 (9.1) | 15 (4.6) | QR/Ordinary/Pendant | 14.0 (202) | 12 @ 50 (3.5) |
| 11.2 (161) | 20 @ 51 (3.5) | SR/Ordinary/Any | 11.2 (161) | 25 @ 29 (2.0) |
| 14.0 (202) | 20 @ 33 (2.3) | 16.8 (236) | 20 @ 23 (1.6) |
| 25.2 (360) | 20 @ 10 (0.7) | QR/Ordinary/Any | 25.2EC (360EC) | 13 @ 22 (1.5) |
| 5 (1.5) | QR/Ordinary/Pendant | 14.0 (202) | 12 @ 50 (3.5) |

≤1 gal (4 L) Cartoned Only | 30 (9.1) | 20 (6) | SR/Ordinary/Any | 11.2 (161) | 20 @ 51 (3.5) |
| 14.0 (202) | 20 @ 33 (2.3) | 16.8 (236) | 20 @ 23 (1.6) |
| 25.2 (360) | 20 @ 10 (0.7) | QR/Ordinary/Any | 25.2EC (360EC) | 13 @ 22 (1.5) |

≤48 oz (1.4 L) Uncarton and/or Cartoned | 30 (9.1) | 15 (4.6) | SR/Ordinary/Any | 11.2 (161) | 35 @ 29 (2.0) |
| 14.0 (202) | 35 @ 18 (1.2) | 16.8 (236) | 35 @ 13 (0.9) |
| 25.2 (360) | 35 @ 7 (0.5) | QR/Ordinary/Any | 25.2EC (360EC) | 18 @ 22 (1.5) |

Notes: 1. See Section D.1 for explanation of abbreviations. See Section D.2.2 for fire protection schemes.
2. The K19.8 (K280) sprinkler is not acceptable for use in this protection table.
### Table 18. Palletized/Solid Pile Storage of Groups 1 through 4 Water-Miscible Liquids in Plastic or Glass Containers

<table>
<thead>
<tr>
<th>Liquid Type (Note 2)</th>
<th>Container Size, Type</th>
<th>Packaging Type</th>
<th>Maximum Ceiling Height ft (m)</th>
<th>Maximum Storage Height ft (m)</th>
<th>Ceiling Sprinkler Protection</th>
<th>K-factor gpm/psi1/2 (L/min/bar1/2)</th>
<th>Design, # of Sprinklers @ Pressure psi (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤16 oz (500 ml), Any</td>
<td>Cartoned Only</td>
<td>30 (9.1)</td>
<td>12 (3.7)</td>
<td>QR/Ordinary/Pendant</td>
<td>14.0 (202)</td>
<td>12 @ 50 (0.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SR/Ordinary/Any</td>
<td>11.2 (161)</td>
<td>25 @ 51 (3.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14.0 (202)</td>
<td>25 @ 33 (2.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.8 (235)</td>
<td>25 @ 23 (1.6)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>25.2 (360)</td>
<td>25 @ 10 (0.7)</td>
</tr>
<tr>
<td></td>
<td>≤16 oz (500 ml), Any</td>
<td>Cartoned Only</td>
<td>8 (2.4)</td>
<td></td>
<td>QR/Ordinary/Any</td>
<td>11.2 (161)</td>
<td>15 @ 51 (3.5)</td>
</tr>
<tr>
<td></td>
<td>≤6 oz (180 ml), Any</td>
<td>Cartoned Only</td>
<td>30 (9.1)</td>
<td>15 (4.6)</td>
<td>QR/Ordinary/Pendant</td>
<td>14.0 (202)</td>
<td>15 @ 33 (2.3)</td>
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<td></td>
<td>SR/Ordinary/Any</td>
<td>16.8 (235)</td>
<td>15 @ 23 (1.6)</td>
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<td></td>
<td></td>
<td></td>
<td>25.2 (360)</td>
<td>15 @ 10 (0.7)</td>
</tr>
<tr>
<td></td>
<td>≤59 oz (1.75 L),</td>
<td>Cartoned Only</td>
<td>30 (9.1)</td>
<td>20 (6.1)</td>
<td>QR/Ordinary/Pendant</td>
<td>14.0 (202)</td>
<td>12 @ 50 (0.4)</td>
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<td>11.2 (161)</td>
<td>20 @ 29 (2.0)</td>
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<td></td>
<td></td>
<td>14.0 (202)</td>
<td>20 @ 18 (1.2)</td>
</tr>
<tr>
<td></td>
<td>≤59 oz (1.75 L),</td>
<td>Cartoned Only</td>
<td>17 (5.2)</td>
<td>17 (5.2)</td>
<td>QR/Ordinary/Any</td>
<td>14.0 (202)</td>
<td>12 @ 50 (0.4)</td>
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<td>Glass or Plastic</td>
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<td>SR/Ordinary/Any</td>
<td>14.0 (202)</td>
<td>20 @ 18 (1.2)</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>16.8 (235)</td>
<td>20 @ 13 (0.9)</td>
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<td></td>
<td></td>
<td>22.4 (322)</td>
<td>12 @ 7.5 (0.5)</td>
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<td>25.2 (360)</td>
<td>12 @ 20 (1.4)</td>
</tr>
<tr>
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<td>≤6.5 gal (25 L),</td>
<td>Uncartonized or Cartoned</td>
<td>30 (9.1)</td>
<td>20 (6.1)</td>
<td>QR/Ordinary/Pendant</td>
<td>14.0 (202)</td>
<td>12 @ 50 (0.4)</td>
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<td></td>
<td>SR/Ordinary/Any</td>
<td>11.2 (161)</td>
<td>30 @ 13 (0.9)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>14.0 (202)</td>
<td>30 @ 8 (0.6)</td>
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<td></td>
<td></td>
<td></td>
<td>≥16.8 (235)</td>
<td>30 @ 7 (0.5)</td>
</tr>
</tbody>
</table>

Notes:
1. See Section D.1 for explanation of abbreviations. See Section D.2.2 for fire protection schemes.
2. See Section 3.1.1 for definitions of Groups 1 through 4 water-miscible liquids.
3. The K19.6 (K280) sprinkler is not acceptable for use in this protection table.
2.4.8 Yard Storage: Any Container Type

2.4.8.1 Provide manual protection consisting of yard hydrants within 200 ft (60 m) of all outside ignitable liquid storage areas. Provide manual foam protection for critical large or high-value storage areas containing liquids with flash points below 200°F (93°C). Manual foam protection can be provided by a fixed water-spray system, fixed monitor nozzles, or mobile monitor and hose nozzles. Design the system in accordance with Data Sheet 4-7N, Low Expansion Foam Systems.

2.5 Operation and Maintenance

Thorough basic equipment and building maintenance programs are fundamental components of any ignitable liquid storage facility. Such programs contribute to reducing the potential for a fire, as well as reducing the frequency and severity of such events.

2.5.1 Establish a complete maintenance program designed to ensure equipment is operating as it has been engineered to operate. Refer to Data Sheet 9-0/17-0, Maintenance and Inspection, to evaluate existing programs or as a guide to developing new ones. Include mechanical and electrical equipment in maintenance programs for equipment handling and areas containing ignitable liquids. Follow preventive maintenance schedules closely to prevent the creation of an ignition source (e.g., equipment breakdown and overheating, improperly sealed hazardous area rated electric equipment).

2.5.2 Relocate equipment needing repair or maintenance that uses a cutting torch or other hot work operation to an appropriately arranged and isolated designated hot work location.

2.6 Training

Thorough employee training is a fundamental component of any ignitable liquid storage facility. Such training contributes to reducing the potential for a fire, as well as reducing the frequency and severity of such events. Proper employee training for spill response and lift truck operation can help ensure that a small fire is contained and does not escalate into a major loss.

2.6.1 Create a training program for all employees (including lift truck operators, emergency response team members, and security personnel) who have access to or work in areas containing ignitable liquid storage. Provide training for all new employees, with refresher programs as needed. At minimum, ensure the program covers the following subjects:

A. The hazards created by the liquids and their associated containers
B. Proper liquid/container handling procedures (i.e., lift truck operations, liquid transport through the facility, etc.)
C. Emergency procedures, including the location, proper type and proper use of fire extinguishers and small hose stations
D. Fixed extinguishing systems operation and function
E. The consequences of failing to follow the procedures

2.7 Human Factor

2.7.1 At locations storing ignitable liquids, establish an emergency response plan designed to control the extent of damage due to fire. At minimum, ensure the plan covers the following subjects:

A. Prompt fire service notification
B. Availability of provided fire protection features
C. Spill-response procedures aimed at limiting spill size (e.g., prompt removal of breached containers), containing released liquid (e.g., use of sand bags or other barriers), and elimination of all ignition sources that may be exposed by the spill or flammable vapors until the spill is cleaned up.

The extent of the emergency response plan, including spill-response procedures, will depend on the hazards present, facility size, availability of emergency response personnel from surrounding communities (e.g., public fire service, spill response teams), and local, state, and federal regulations.
2.7.2 Familiarize the facility’s emergency response team members and the public fire service with the location of ignitable liquids storage, as well as the emergency response plan. Use emergency response drills to reinforce the employee training programs (including emergency response team) and assist the fire service in pre-fire planning.

2.7.3 Arrange security rounds to include all areas storing ignitable liquids. Train security personnel to recognize and provide prompt notification of a leak.

2.7.4 Provide a raw materials inspection program to ensure delivery of expected liquids and prevent the introduction of incompatible liquids into a storage facility. Only accept, ship and use containers that comply with U.S. Department of Transportation (DOT), United Nations, or equivalent specifications. Maintain the vapor space no less than that permitted by the specific regulation.

2.7.5 Conduct fusible drum plug supervision in accordance with the following recommendations at locations where FM Approved drum plugs are used.

2.7.5.1 Develop a management reporting system that includes:
   A. Qualified personnel to be responsible for program implementation.
   B. Periodic management audits to ensure the program is implemented as intended.

2.7.5.2 Create purchasing requirements that include:
   A. A list of qualified suppliers.
   B. A list of FM Approved plugs that are installed by each supplier.

2.7.5.3 Develop drum inspection requirements for receiving and storage areas that include:
   A. Visual inspections to ensure FM Approved plugs are installed on all incoming drums.
   B. Recorded incoming drum inspections.
   C. An up-to-date list of qualified suppliers and FM Approved drum plugs.
   D. Clear authorization to reject any shipments containing non-Approved drum plugs.
   E. Reporting requirement for any unsatisfactory conditions to ensure prompt corrective measures.

2.7.5.4 Provide awareness training for employees who receive and handle drums fitted with FM Approved plugs. Ensure the training addresses the following:
   A. Role of FM Approved drum plugs and proper storage practices
   B. Potential consequences of unapproved plugs and improper storage
   C. Recognizing FM Approved and unapproved plugs
   D. Inspection and reporting procedures
   E. Initial training and periodic refreshers

2.7.5.5 Provide documentation of all procedures, suppliers, inspection records, and training. Ensure documentation is maintained in a central location on site that is accessible for loss prevention audits.

2.7.5.6 Use Management of Change procedures to:
   A. Maintain an up-to-date roster of designated employees and their role in plug supervision.
   B. Communicate new suppliers and plug manufacturers to all areas of the supervision program.

2.7.6 Clearly label all containers filled with ignitable liquids. Inspect drums for leaks upon receipt, when in use, and while stored. Promptly remove any leaking, corroded, or damaged drums, and immediately clean up any spillage and dispose of it in a manner acceptable to the authority having jurisdiction.

2.7.7 Strictly control all changes in storage arrangements, locations, and types of ignitable liquids. Conduct a full review of all planned changes with qualified loss prevention consultants as well as other authorities having jurisdiction before the project begins.
2.8 Ignition Source Control

A basic design goal for occupancies that contain ignitable liquids is the elimination and careful control of all potential ignition sources. Prevention measures should prevent contact of an ignition source with any flammable vapor-air mixture.

2.8.1 Use Table 19 to determine areas needing rated electrical equipment. Ordinary electrical equipment is suitable for liquids with flash points above 100°F (38°C) if they are not heated above their flash point and there is no possibility of lower flash point liquids being introduced later.

Table 19. Electrical Equipment Ratings, Lift Truck Ratings and Ventilation Rates for Ignitable Liquids Storage Occupancies

<table>
<thead>
<tr>
<th>Liquid Type</th>
<th>Container Size</th>
<th>Electrical Equipment Rating within 6 ft (1.8 m) of Floor Level</th>
<th>Lift Truck Rating for Handling or Transporting Liquids</th>
<th>Ventilation Rates per Unit Floor Area cfm/ft² (m³/min/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP ≤100°F (38°C) AND BP&lt;100°F (38°C)</td>
<td>Any</td>
<td>Class 1 Division 2</td>
<td>Class 1 Zone 2</td>
<td>Type EE or DY</td>
</tr>
<tr>
<td>FP ≥100°F (38°C) ≤6.5 gal (25 L)</td>
<td>Ordinary</td>
<td>Ordinary</td>
<td>Type EE or DY</td>
<td>Natural</td>
</tr>
<tr>
<td>&gt;6.5 gal (25 L)</td>
<td>Class 1 Division 2</td>
<td>Class 1 Zone 2</td>
<td>Type EE or DY</td>
<td>0.25 (0.08)</td>
</tr>
<tr>
<td>FP &gt;100°F (38°C)</td>
<td>Any</td>
<td>Ordinary</td>
<td>Ordinary</td>
<td>Ordinary</td>
</tr>
</tbody>
</table>

Note: FP = flash point, and BP = boiling point.

2.8.2 Use Table 19 to determine when lift trucks that are FM Approved for Class 1, Division 2 locations are needed to handle and/or transport liquid storage. It is acceptable to use electric Type E, gasoline Type GS, diesel Type DS, and LP-gas Type LPS to transport all liquid types outdoors as long as the lift trucks are well maintained. Air-powered or manually-operated hoists, hand trucks, or other manual equipment are acceptable and are generally preferred for use with all ignitable liquids. Do not use hydrogen fuel cell lift trucks for handling ignitable liquids since they are not currently rated for hazardous location use and may create an explosion hazard if they are fueled in the building where they are being used.

2.8.3 Provide grounding in accordance with Data Sheet 5-8, Static Electricity, Data Sheet 5-10, Protective Grounding for Electric Power Systems and Equipment, and NFPA 70, National Electrical Code, Articles 250 and 500, for equipment subject to static accumulations, such as racks, ventilating ducts, hoists, etc. Proper grounding of equipment reduces the potential for buildup of electric charge on separated pieces of equipment due to static accumulations or stray electric currents.

2.8.4 Prohibit smoking or the use of open flames in all rooms, buildings, or outdoor storage areas that are used for the storage of ignitable liquids. Post conspicuous signs to define hazardous areas and state restrictions for the area.

2.8.5 When heating rooms or buildings that contain ignitable liquid storage, use a system that does not introduce an ignition source (e.g., steam, hot water, or hazardous location rated electric heat). Direct natural gas/fuel oil-fired make-up air heaters are acceptable if the heating unit is located outside the room or building and there is no air recirculation. Keep heating equipment temperatures below the auto-ignition point of the liquids present in the room. If liquids with a closed-cup flash point below 100°F (38°C) are present, keep the heaters at least 5 ft (1.5 m) above the floor level.

2.8.6 Do not use non-rated portable electrical equipment in areas requiring rated electrical equipment. If such equipment must be temporarily introduced, treat this as hot work and follow the permit precautions. As with other hot work, if the precautions cannot be taken, do not issue the permit and do not use the non-rated electrical equipment.

2.8.7 Do not allow hot work of any kind in areas (indoors and outdoors) storing ignitable liquids. Instead, use methods that do not create a potential ignition source, or relocate any hot work to a nonhazardous location. When relocation is not possible, use the FM Global Hot Work Permit System. Precautions are listed on the FM Global Hot Work Permit itself (also see Data Sheet 10-3, Hot Work Management). Some of the minimum requirements include:

   A. Automatic sprinkler protection and special protection systems must be in service. Provide charged small hose or fire extinguishers at the work area.
B. Remove ignitable liquid storage from the area. Remove or cover with a fire-resistive tarpaulin all other combustibles within 35 ft (11 m) of the work (see Data Sheet 1-0, Safeguards During Construction).

C. Keep mechanical ventilation in the room/building in operation. Use a portable combustible gas analyzer before and during the work. If any detectable readings are obtained, work cannot begin or continue until the source is found and suitably mitigated such that the concentration is maintained below 10% of the LEL.

D. Do not reintroduce the ignitable liquid storage until after the required fire watch and monitoring period have elapsed and a final check of the area has been completed.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Liquid Evaluation

The first step in evaluating the storage of ignitable liquids is to determine the actual fire hazard presented by the liquid. Current labeling practices required by many codes and liquid classification schemes are not a good indication of the fire hazard of a liquid. Even the measurable physical properties of liquids do not always provide enough information to determine the fire hazard created by a particular stored liquid.

Existing liquid classification schemes are based on a liquid’s closed-cup flash point. Some assign numerical values, while others assign labels (e.g., flammable, combustible) to flash point ranges. Some classification schemes have many subdivisions, while others only define a few. What they have in common is that none of these schemes define the fire hazard created by the liquid and, in many cases, create confusion about the severity of the hazard.

The current liquid classification scheme described in NFPA 30, Flammable and Combustible Liquids Code, is as follows:

“Flammable liquids” have closed-cup flash points below 100°F (38°C), and vapor pressures not exceeding 40 psia (2.8 bar) at 100°F (38°C) (thus excluding liquefied petroleum gases, liquefied natural gases, and liquefied hydrogen). Flammable liquids are referred to as “Class 1 liquids” and are subdivided as follows:

- Class IA liquids have flash points below 73°F (23°C) and boiling points below 100°F (38°C).
- Class IB liquids have flash points below 73°F (23°C) and boiling points at or above 100°F (38°C).
- Class IC liquids have flash points at or above 73°F (23°C) and below 100°F (38°C). Examples are styrene, methyl isobutyl ketone, isobutyl alcohol, and turpentine.

“Combustible liquids” have closed-cup flash points at or above 100°F (38°C). They are referred to as either Class II or Class III liquids and are subdivided as follows:

- Class II liquids have flash points at or above 100°F (38°C) and below 140°F (60°C).
- Class IIIA liquids have flash points at or above 140°F (60°C) and below 200°F (93°C).
- Class IIIB liquids have flash points at or above 200°F (93°C).

The current liquid classification scheme followed by the U.S. Transportation Code and the U.N. Transportation Recommendations classify ignitable liquids into two basic groups:

- Flammable Liquids have a flash point at or below 141°F (60.6°C).
- Combustible Liquids have a flash point above 141°F (60.6°C) and below 200°F (93°C)

The liquid classification scheme based on flash point started when liquids were commonly mixed in open vessels or tanks and a measure of the potential for ignition was needed. The flash point served this purpose well; however, it does not provide any measure of the fire hazard created by storing the liquids in various containers and in various storage arrays. Flash point only provides some measure of how difficult the ignition of a liquid may be.

The fire hazard of an ignitable liquid is determined by both inherent physical properties of the liquid and external factors such as container construction, container size, storage arrangement, and building construction. Two measures of fire severity are heat release rate and flame height. For liquid fires, the heat release rate is controlled by the surface area of the liquid, the liquid’s heat of combustion, and the mass loss rate of the liquid. The flame height is controlled by the fire’s heat release rate. The heat of combustion...
and mass loss rate are physical properties of the liquid. The surface area available to burn is dependent on numerous external factors such as liquid release method (spray release, liquid stream, catastrophic mass release), floor surface and pitch (rough surface and/or floor pitch will limit liquid spread), and container construction (combustible containers will release liquid while most noncombustible containers will retain liquid if properly protected). Tables 20 and 21 provide calculated heat release rates and flame heights for various liquids in a fixed pool area and for flowing liquid fires.
### Table 20. Ignitable Liquid Spill Fire Data: Comparison of Various Spill Rates and Liquids

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Closed-Cup Flash Point °F (°C)</th>
<th>Tank Volume (gal/kg)</th>
<th>Pipe Diameter (in.)</th>
<th>Flow Rate (kg/s)</th>
<th>Flow Rate (gpm)</th>
<th>Discharge Duration (s)</th>
<th>Pool Diameter (m)</th>
<th>Pool Diameter (ft)</th>
<th>Pool Area (m²)</th>
<th>Pool Area (ft²)</th>
<th>Fire Duration (s)</th>
<th>Mass Loss Rate (kg/m²s)</th>
<th>Heat Release Rate (kW)</th>
<th>Flame Height (m)</th>
<th>Flame Height (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heptane</td>
<td>25 (-4)</td>
<td>55/123</td>
<td>0.5</td>
<td>12.7</td>
<td>0.1</td>
<td>2.3</td>
<td>1231</td>
<td>0.93</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>1232</td>
<td>0.144</td>
<td>4,030</td>
<td>5.6</td>
</tr>
<tr>
<td>Heptane</td>
<td>25 (-4)</td>
<td>56/123</td>
<td>1</td>
<td>25.4</td>
<td>0.4</td>
<td>9.3</td>
<td>307.6</td>
<td>1.88</td>
<td>6</td>
<td>3</td>
<td>30</td>
<td>309.9</td>
<td>0.145</td>
<td>16,583</td>
<td>9.5</td>
</tr>
<tr>
<td>Heptane</td>
<td>25 (-4)</td>
<td>56/123</td>
<td>1</td>
<td>25.4</td>
<td>0.64</td>
<td>14.9</td>
<td>190</td>
<td>2.4</td>
<td>8</td>
<td>5</td>
<td>49</td>
<td>194.4</td>
<td>0.146</td>
<td>27,212</td>
<td>11.5</td>
</tr>
<tr>
<td>Heptane</td>
<td>25 (-4)</td>
<td>57/123</td>
<td>2</td>
<td>50.8</td>
<td>1.6</td>
<td>37.1</td>
<td>76.9</td>
<td>3.8</td>
<td>12</td>
<td>11</td>
<td>122</td>
<td>82.3</td>
<td>0.146</td>
<td>68,219</td>
<td>16.3</td>
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<td>Heptane</td>
<td>25 (-4)</td>
<td>58/123</td>
<td>3</td>
<td>76.2</td>
<td>3.6</td>
<td>83.7</td>
<td>33.3</td>
<td>5.7</td>
<td>19</td>
<td>26</td>
<td>275</td>
<td>41</td>
<td>0.146</td>
<td>153,493</td>
<td>22.1</td>
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<tr>
<td>Heptane</td>
<td>25 (-4)</td>
<td>110/247</td>
<td>1</td>
<td>25.4</td>
<td>0.4</td>
<td>9.3</td>
<td>615.8</td>
<td>1.88</td>
<td>6</td>
<td>3</td>
<td>30</td>
<td>617</td>
<td>0.144</td>
<td>16,469</td>
<td>9.5</td>
</tr>
<tr>
<td>Heptane</td>
<td>25 (-4)</td>
<td>220/494</td>
<td>1</td>
<td>25.4</td>
<td>0.4</td>
<td>9.3</td>
<td>1229</td>
<td>1.88</td>
<td>6</td>
<td>3</td>
<td>30</td>
<td>1231</td>
<td>0.144</td>
<td>16,469</td>
<td>9.5</td>
</tr>
<tr>
<td>Decane</td>
<td>115 (46)</td>
<td>55/131</td>
<td>1</td>
<td>25.4</td>
<td>0.48</td>
<td>10.4</td>
<td>306.6</td>
<td>2.3</td>
<td>8</td>
<td>4</td>
<td>45</td>
<td>311</td>
<td>0.112</td>
<td>18,939</td>
<td>9.7</td>
</tr>
<tr>
<td>Dodecane</td>
<td>165 (74)</td>
<td>55/134</td>
<td>1</td>
<td>25.4</td>
<td>0.44</td>
<td>9.4</td>
<td>306.6</td>
<td>2.5</td>
<td>8</td>
<td>5</td>
<td>53</td>
<td>312</td>
<td>0.101</td>
<td>20,030</td>
<td>9.8</td>
</tr>
<tr>
<td>Ethyl Ether</td>
<td>-49 (-45)</td>
<td>55/148</td>
<td>1</td>
<td>25.4</td>
<td>0.42</td>
<td>9.4</td>
<td>307.6</td>
<td>1.7</td>
<td>6</td>
<td>2</td>
<td>24</td>
<td>310</td>
<td>0.187</td>
<td>11,333</td>
<td>8.1</td>
</tr>
<tr>
<td>Acetone</td>
<td>-4 (-20)</td>
<td>55/123</td>
<td>1</td>
<td>25.4</td>
<td>0.46</td>
<td>10.3</td>
<td>307.6</td>
<td>2.2</td>
<td>7</td>
<td>4</td>
<td>41</td>
<td>314.1</td>
<td>0.141</td>
<td>14,954</td>
<td>8.7</td>
</tr>
<tr>
<td>IPA</td>
<td>53 (12)</td>
<td>55/123</td>
<td>1</td>
<td>25.4</td>
<td>0.46</td>
<td>10.3</td>
<td>307.6</td>
<td>2.7</td>
<td>9</td>
<td>6</td>
<td>62</td>
<td>317.5</td>
<td>0.108</td>
<td>17,932</td>
<td>9.1</td>
</tr>
</tbody>
</table>

### Table 21. Ignitable Liquid Pool Fire Data: Comparison of Fixed Pool Diameter Fires for Different Liquids with Fixed Liquid Depth

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Closed-Cup Flash Point °F (°C)</th>
<th>Pool Diameter (m)</th>
<th>Pool Diameter (ft)</th>
<th>Pool Area (m²)</th>
<th>Pool Area (ft²)</th>
<th>Mass Loss Rate (kg/m²s)</th>
<th>Chemical Heat of Combustion (kJ/g)</th>
<th>Heat Release Rate (kW)</th>
<th>Flame Height (m)</th>
<th>Flame Height (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heptane</td>
<td>25 (-4)</td>
<td>2.4</td>
<td>8</td>
<td>5</td>
<td>49</td>
<td>0.144</td>
<td>41.2</td>
<td>26,839</td>
<td>11.4</td>
<td>38</td>
</tr>
<tr>
<td>Decane</td>
<td>115 (46)</td>
<td>2.4</td>
<td>8</td>
<td>5</td>
<td>49</td>
<td>0.112</td>
<td>40.7</td>
<td>20,622</td>
<td>10.0</td>
<td>33</td>
</tr>
<tr>
<td>Dodecane</td>
<td>165 (74)</td>
<td>2.4</td>
<td>8</td>
<td>5</td>
<td>49</td>
<td>0.101</td>
<td>40.4</td>
<td>18,459</td>
<td>9.5</td>
<td>31</td>
</tr>
<tr>
<td>Ethyl Ether</td>
<td>-49 (-45)</td>
<td>2.4</td>
<td>8</td>
<td>5</td>
<td>49</td>
<td>0.187</td>
<td>26.7</td>
<td>22,587</td>
<td>10.5</td>
<td>34</td>
</tr>
<tr>
<td>Acetone</td>
<td>-4 (-20)</td>
<td>2.4</td>
<td>8</td>
<td>5</td>
<td>49</td>
<td>0.141</td>
<td>27.9</td>
<td>17,797</td>
<td>9.3</td>
<td>31</td>
</tr>
<tr>
<td>IPA</td>
<td>53 (12)</td>
<td>2.4</td>
<td>8</td>
<td>5</td>
<td>49</td>
<td>0.108</td>
<td>29</td>
<td>14,169</td>
<td>8.3</td>
<td>27</td>
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</tbody>
</table>
The above approach to evaluating liquid fire hazard indicates that hydrocarbon liquids will produce comparable heat release rates regardless of flash point. Since the heat release rate provides a measure of the fire severity, subdividing hydrocarbon liquids by flash point alone appears meaningless.

Another factor to consider is the ability to extinguish a liquid pool fire with ceiling sprinkler discharge alone. Previous FM Global testing showed ceiling sprinklers were successful in extinguishing pool fires involving liquids with a closed-cup flash point greater than 200°F (93°C). This result was also supported in more recent FM Global tests on vegetable and motor oils. Using this criteria, hydrocarbon liquids could be divided into two groups: liquids that cannot be extinguished with ceiling sprinkler discharge and liquids that can be extinguished with ceiling sprinkler discharge. The break point would be a closed-cup flash point of 200°F (93°C).

The FM Global test results on motor oil and vegetable oil provided a break point to use for the evaluation of liquids with a flash point greater than 200°F (93°C). The required level of fire protection for vegetable oils in plastic containers is less than that required for motor oil in plastic containers. The closed-cup flash point of the tested vegetable oil was 450°F (232°C). The motor oil tested had a flash point of 375°F (191°C). The main difference between the two tested liquids was the amount of energy needed to ignite the liquids. The higher flash and fire points of the vegetable oil allowed for the use of a reduced protection scheme (i.e., no barriers and one line of in-rack sprinklers) because the released oil was more difficult to ignite and, when ignited, was very easily cooled and extinguished by sprinkler discharge.

Other material/liquid properties that may impact the fire hazard of a liquid include water miscibility, liquid mixtures and emulsions, liquid viscosity, low boiling point liquids (i.e., boiling point below 100°F [38°C]), and liquids that are heavier than water (i.e., specific gravity above 1).

Ultimately, when considering the fire hazard created by liquids, determining if the liquid will burn is the critical factor. If it burns, the liquid creates a significant fire hazard for storage occupancies. Even liquids that create limited fire hazards will create an unacceptable fire in a storage occupancy because they can still create a large-area ignition source. Igniting solid materials in multiple flue spaces is beyond the design basis for current sprinkler criteria for solid commodities. Unfortunately, current codes do not support identifying liquids that will burn. Most codes ignore liquids with flash points greater than 140°F (40°C) and these can burn down a building just as easily as the liquids that require labeling.

### 3.1.1 Water-Miscible Liquids

See Appendix A for the definition of water-miscible.

Historically, water-miscible ignitable liquids were thought to require significantly less protection than normal hydrocarbon liquids due to the fact that they can be diluted with water to a point where they cease to burn. This approach actually allowed certain mixtures of water and ignitable liquids to be protected as a solid commodity. Water-miscible liquids do generally have lower heat release rates and low flame radiation (due to limited soot production). Also, as the water percentage of the mixture rises, the flash point and fire point of the mixture increase while the heat of combustion and heat release rate decrease. At some point, the mixture will cease to have a fire point but may still have a flash point. Mixtures that do not have a fire point will not burn. Conversely, if the mixture has a fire point, it will burn and can create a pool fire. Unfortunately, this means products with limited amounts of a water-miscible liquid and a fire point have the potential for creating a pool fire if the liquid release is not controlled or contained during a fire. This could allow fire spread well beyond the area of fire origin. Mixtures that have fire points must always be considered ignitable liquids.

There are only a small number of ignitable liquids that meet the definition of water-miscible provided in this data sheet. The majority of liquids that meet the definition are low molecular weight alcohols and acetone. Only the liquids listed in Table 22 should be considered water-miscible. If a liquid is thought to be water-miscible, it must be confirmed by testing a range of volume percentages to clearly demonstrate its ability to mix in all proportions with water.

Water-miscible liquids do mix with water. However, they are also lighter than water so they float on its surface. The majority of the mixing in a sprinklered pool fire scenario is due to sprinkler discharge impacting the liquid surface. Full-scale tests by FM Global have shown that, although mixing does occur, it is a very slow process and should not be depended on to reduce fire protection needs in a storage arrangement.

Some protection criteria required for water-miscible liquids as a general group can be reduced due to the lower heat release rates and lower flame radiation (e.g., location and construction requirements, sprinkler protection for liquids in metal containers). Some protection criteria (e.g., drainage requirements) can be
reduced due to the expected dilution effect of water. In other cases, water-miscible liquids need to be broken down by the specific liquid, liquid concentration, and storage container construction (e.g., sprinkler protection for liquids in plastic containers). Since plastic or glass containers cannot prevent the release of a water-miscible liquid during a fire, the liquid type and concentration must be considered. All water-miscible liquids do not present the same fire hazard. Acetone creates a more severe fire hazard than isopropyl alcohol (IPA). Unfortunately, fire testing conducted to date has only looked at alcohols. This base of test data allows the grouping of all water-miscible alcohols by volume percent. One series of small-scale testing indicates that 80% acetone presents a fire hazard similar to 100% IPA. Since different levels of fire protection criteria are possible for various mixtures of some miscible liquids and water, mixtures with similar fire hazards were grouped.

### Table 22. Water-Miscible Liquid Groupings

<table>
<thead>
<tr>
<th>Group</th>
<th>Volume Percent Range</th>
<th>Alcohol (Note 1)</th>
<th>Acetone</th>
<th>Ethylene Glycol, Propylene Glycol (Note 2)</th>
<th>Acetic Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>71 - 100</td>
<td>16 - 80</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
</tr>
<tr>
<td>2</td>
<td>51 - 70</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
</tr>
<tr>
<td>3</td>
<td>31 - 50</td>
<td>DNA</td>
<td>&gt;80</td>
<td>≥90</td>
<td>≥90</td>
</tr>
<tr>
<td>4</td>
<td>21 - 30</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
</tr>
<tr>
<td>5</td>
<td>0 - 20</td>
<td>0 - 15</td>
<td>≤80</td>
<td>&lt;90</td>
<td>&lt;90</td>
</tr>
</tbody>
</table>

Notes:
1. Methyl alcohol, ethyl alcohol, n-propyl alcohol, isopropyl alcohol, tert-butyl alcohol, allyl alcohol.
2. For glycol-water mixtures less than or equal to 80 glycol, see Section 2.1.3.7.
3. DNA - does not apply.

Miscible liquid mixtures in plastic or glass containers that are not included in the groups have not been evaluated. Use the guidelines in Table 12 to determine acceptable fire protection for these liquids.

### 3.1.2 Emulsions

There are a number of products that consist of a water base mixed with various percentages of immiscible ignitable liquids and solids. Many of these are emulsions (i.e., the immiscible ignitable liquid does not separate out of the mixture). A common example of this type of product is a water-borne paint or coating. Latex paints generally have little or no ignitable liquid content. Some newer paints have various percentages of ignitable liquid in a water base. The ignitable liquids can be water-miscible or immiscible. Bench-scale testing on a large number of paint products with up to 20% immiscible ignitable liquid has shown these materials to present no measurable fire hazard. Many of these materials cannot be easily tested using standard flash or fire point test methods. However, efforts to ignite larger quantities of liquid than required by these tests also failed to produce any sustained combustion. All emulsion products with unknown ignitable liquid content require testing to confirm if the product has a fire point.

### 3.1.3 Viscous Liquids/Viscous Mixtures

Viscosity is measured by many different types of tests. Many of the measurements were developed for a particular type of liquid at a fixed temperature. It is not possible to convert between most of the viscosity measurements. One unit of dynamic (absolute) viscosity is a centipoise (cP). One cP is equivalent to 6.72 x 10^-4 lb/sec-ft or 0.01 g/cm-sec. The viscosity of several liquids (at 70°F [21°C]) are as follows:

- Water: 1.0 cP
- Gasoline: 0.65 cP
- Acetone: 0.35 cP
- Lubricating oil (SAE 10): 60 cP
- Glycerin: 1000 cP
- Honey: 10,000 cP
- Asphalt: >100,000 cP

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A common unit of measure for kinematic (ratio of kinematic viscosity and density) viscosity is centistokes (cSt). At 68°F (20°C), water has a kinematic viscosity of about 1 cSt.

An important benefit of viscous liquids is their reduced flow capacity. Highly viscous liquids will resist free flow, which results in reduced surface area. As discussed earlier, surface area has a direct impact on liquid fire severity. Unfortunately, the viscosity of many materials decreases with elevated temperatures. Since current viscosity measurement techniques do not provide viscosities at fire temperatures, a reduction in fire hazard for viscous homogenous materials cannot be determined.

There are other liquids that consist of a mixture of solids and an ignitable liquid. In cases where there is a high solid content, a reduction in fire hazard is expected. Liquids with a viscosity of 10,000 cp and less than 10% ignitable liquid, or a viscosity of 100,000 cp and less than 50% ignitable liquid, can be protected using reduced protection criteria. Straight interpolation may be used to calculate the maximum solvent content for mixtures with viscosities between 10,000 cp and 100,000 cp. One example is automobile repair putty, which consists of a viscous base material combined with a small quantity of low flash point solvent.

Liquid drainage systems are not needed for any liquid with a viscosity greater than 10,000 cP. Even though these liquids may experience a reduction in viscosity when exposed to a fire, if the sprinkler protection is adequate, the liquids should cool quickly on the floor. The reduced flow characteristics of a highly viscous liquid negates the effectiveness of a drainage system in removing the liquid.

3.1.4 Liquids with Boiling Point Below 100°F (38°C)

No testing has been conducted on these liquids. Their low boiling point results in rapid vaporization when released. This creates the potential for the formation of an explosive cloud if the liquid is spilled, or the quick buildup of pressure in a sealed container exposed to fire. The impact on the overall fire hazard may be limited. Quick vaporization produces a high mass loss rate that will quickly reduce pool area. These two factors may cancel each other’s impact on the overall heat release rate. The key concerns with these liquids is the prevention of a large liquid release that could result in an explosion, and the prevention of container overpressurization during a fire.

3.1.5 Liquids with Specific Gravity Above 1

These liquids can be extinguished by water if the water is given the opportunity to build up over the liquid’s surface. Emergency floor drainage is not required for this type of liquid storage as long as adequate containment can be provided to ensure water buildup over the ignitable liquid’s surface. The overall fire hazard is not expected to be significantly reduced since the liquid fire would not be extinguished until water could completely cover its surface.

3.1.6 Atypical Ignitable Liquids

3.1.6.1 Liquids with Closed-Cup Flash Points At or Above 450°F (232°C)

Based on the results of several research test programs, FM Global has defined a closed-cup flash point threshold at which liquids will not support fire spread across an unheated liquid pool. This does not mean these liquids will not burn; in fact, they still represent a severe fire hazard when stored in small plastic containers or larger containers with cardboard packaging, and when they are heated above 150°F (65°C) or pumped.

3.1.6.2 Silicone Fluids and Silicone Emulsions

Historically, silicone fluids have been thought to present a minimal fire hazard because it was believed the silicone dioxide ash produced by burning silicone fluids would act to coat the liquid surface and extinguish the fire. Unfortunately, large pool fires create significant fire plumes that lift even silicone dioxide ash away from the liquid surface. Both small-scale and full-scale fire testing of higher viscosity silicone fluids has shown that they do burn and can make very challenging fires. Testing has also shown that relatively low sprinkler discharge rates can quickly extinguish some pool fires.

3.1.6.3 Paste Ink

Paste inks are commonly used in the printing industry. They generally consist of a vegetable oil base mixed with solids. True paste ink will not flow at room temperature without the application of pressure. Fires involving paste ink are usually localized because the ink tends to accumulate on the floor and not readily spread. Protection criteria for paste ink is provided in Data Sheet 7-96, Printing Plants.
3.1.6.4 Water-Based Polyurethane Foam Packaging Systems

Polyurethane packing systems are used at many manufacturing facilities to package product with a secure foam cushion around the product. These polyurethane systems are water-based and consist of two liquid components that, when mixed, react to form polyurethane foam. One component is a polyol. This material is commonly listed with a flash point on its MSDS, however, numerous pool fire tests failed to result in a pool fire. It does not need to be considered an ignitable liquid. When polyurethane is used to manufacture padding for seats or other final products, the polyol is commonly mixed with an oil to create flexible foam. This version of the polyol does burn and is an ignitable liquid.

The second component of the foam packaging is polymethylene polyphenyl isocyanate (PMDI). This is an ignitable liquid; however, the fire hazard it creates is limited. If spilled it will support fire spread across the liquid surface and can release enough energy to activate sprinklers. Sprinkler discharge will quickly extinguish the pool fire. However, a release of this liquid in a general purpose warehouse will result in a very large ignition source. Composite IBC storage of PMDI will quickly fail when exposed to a PMDI pool fire.

3.1.6.5 Butterfat

Fire testing on butterfat demonstrated that it will not support fire spread across the surface of a liquid pool. In large containers, butterfat can be treated like a liquid with a flash point above 450°F (232°C).

3.1.6.6 Unsaturated Polyester Resin (UPR)

UPR is a polyester resin mixture with various amounts of styrene added. UPR is a liquid mixture with the majority of the material being a higher flash point resin and various amounts of styrene, which drives the lower flash point. If the mixture has less than 50% styrene, protection recommendations will vary (refer to Section 2.1.3.6.1). Otherwise, evaluate it as an ignitable liquid using the mixture’s flash point.

Spilled UPR will burn as a pool on the floor. It tends to spread less, and have a slower flame spread, than common low flash point liquids. Heating UPR in a metal container will cause polymerization without significantly overpressurizing the container (i.e., container may partially vent without creating overpressure damage in the building). Palletized relieving-style drum storage of UPR can be protected with sprinklers and does not need drainage.

3.1.6.7 Propylene and Ethylene Glycol Mixtures

Propylene and ethylene glycol are water-miscible, high flash point (FP above 200°F [93°C]) ignitable liquids. One big advantage of these liquids over other high flash point or water-miscible liquids (from a protection standpoint) is they quickly cease to produce a fire point with dilution. Bench-scale testing of both ethylene and propylene glycol has shown they no longer produce a fire point once they have been mixed with 20% by volume water. From a pool fire standpoint, this is positive. 80% by volume or less glycol mixed with water does not need to be treated as an ignitable liquid because the liquids will not burn when in a pool on the floor. However, these liquid mixtures can still impact a fire while they are on the surface of burning cellulosic materials. Intermediate-scale testing of glycol water mixtures being discharged onto burning wooden pallets has shown that mixtures with more than 35% by volume glycol will increase the burning rate of the pallets. Based on this information, protection criteria for glycol water mixtures has been provided in this data sheet.

3.2 Construction and Location

The location and construction features provided for ignitable liquid storage are dependent on both the expected fire severity with protection systems in service and the potential for more severe fire scenarios than were designed for. Container size has a significant impact on the potential for a more severe fire scenario. Fire protection designs for larger containers of low flash point liquids are based on a flowing liquid release that is ignited immediately. The amount of the spill is dependent on the container size. The scenario for metal drums assumes a release from two drums on a single pallet. There is a potential for a larger release or a delayed ignition. Both cases could result in a larger fire that will challenge the provided protection scheme. At a minimum, a cutoff room is needed to segregate ignitable liquid drum storage from other less hazardous occupancies.

Many combustible or brittle containers with low flash point, immiscible ignitable liquids cannot be easily protected with existing sprinkler technology. This type of storage needs to be well cutoff from other occupancies since the confidence level in provided protection is low.
Ignitable liquid storage buildings/cutoff rooms must use noncombustible construction. The high intensity of an ignitable liquid fire could ignite combustible construction even in adequately protected facilities. Additional protection is needed to ensure the integrity of steel columns located in buildings or cutoff rooms where a severe fire is expected.

Liquid control is a critical issue in buildings and cutoff rooms storing ignitable liquids. Based on the type and size of container, the level of liquid control can vary. In storage arrays where large spills are possible, strict liquid control via drainage systems and curbing is needed. Storage arrays of small containers with proven protection schemes do not require drainage or containment.

3.3 Ventilation

Ventilation is an active system designed to prevent the buildup of flammable vapors due to small leaks or spills. These systems must be properly designed and laid out to ensure all floor areas of the warehouse or cutoff room are covered by the system. In large buildings, a test of the system using a smoke generating device may be needed to ensure the system layout is adequate.

3.4 Protection

3.4.1 General

Determining adequate fire protection for the storage of ignitable liquids is not a straightforward effort. In general, there is a lack of full-scale testing to draw conclusions from due to the high cost and potential risk of conducting this type of testing. However, even if the testing is done, the number of variables that could drastically impact the outcome of a test are incalculable. Potential fire scenarios range from a point ignition of a common combustible material in an ignitable liquids storage occupancy to the ignition of the contents of a 350 gal (1,300 m³) IBC that emptied onto the floor.

For containers larger than 6.5 gal (25 L) in size, the fire scenario used to evaluate protection involves a breached container that leaks ignitable liquid at a fixed rate until empty, with ignition after approximately 10 gal (38 L) has been released. The recommended fire protection may not be adequate for the scenario involving the complete release of a large container before ignition in warehouses or cutoff rooms that are larger than the provided sprinkler operating area. Due to the variability of defining fire protection for ignitable liquids, sprinkler protection alone will not ensure adequate protection. Construction features, space separation, and prevention measures must be included in any ignitable liquid warehouse/cutoff room design.

3.4.2 Automatic Sprinklers

Automatic sprinklers are critical for controlling temperatures in an ignitable liquid fire. Lack of sprinklers will result in the loss of buildings used to store these materials. Due to the near immediate growth of an ignitable liquid pool fire, the use of dry sprinkler systems is not recommended without full-scale validation testing. The potential delay time for water delivery will allow unchecked temperature growth at the ceiling, resulting in a large number of sprinklers opening. The very rapid fire growth expected does not allow for a fixed increase (i.e., penalty) in sprinkler operating area. A preaction system could be used as long as the provided detection system ensures water delivery to the sprinklers before the sprinklers operate. Deluge systems provide the best level of protection in unheated facilities.

3.4.3 Special Protection Systems

Special protection systems should be installed with caution in an ignitable liquids storage occupancy. All of these systems have inherent limitations that must be recognized and considered before a system is installed. The systems that present the least number of limitations are foam-water sprinkler and compressed air foam (CAF) systems. In a foam-water sprinkler system the foam concentrate is delivered through sprinkler piping to the fire. In a CAF system, a foam-air-water mixture is delivered though a dedicated piping system to special nozzles that discharge the mixture. Open doors or windows or sprinkler discharge will not impact the effectiveness of the foam. However, these systems are complicated and require the proper operation of a number of mechanical and electrical devices.

Dry chemical systems can easily extinguish an ignitable liquid fire; however, these systems are not tested with sprinklers operating. The water may impact the effectiveness of dry chemical agents. Since an ignitable liquid fire has a very rapid growth rate and these systems are generally activated by heat detectors, it is reasonable to expect simultaneous operation of the sprinkler system and the dry chemical system.
Gaseous extinguishing systems also have some significant limitations. The effectiveness of a gaseous system is severely reduced by openings in the protected space. Openings can be compensated for in the system design. However, to permit an economical design, windows and doors are generally assumed closed. If a door or window fails to close, the system will not be effective. Gaseous extinguishing systems are generally activated by heat detectors and may have built-in discharge delays. Similar to dry chemical systems, gaseous systems will not likely discharge before the operation of ceiling sprinklers. Many of the new clean agents designed to replace Halon 1301 produce large quantities of decomposition products that are highly corrosive. The amount of decomposition is related to the fire size at discharge. If a gaseous extinguishing system is needed, only inert gas-based systems should be used.

3.5 Ignition Source Control

Unlike solid materials, liquids with low flash points do not require much energy to ignite since they produce flammable vapors at ambient temperatures. Preventing the ignition of an accidentally released ignitable liquid prevents an ignitable liquid fire. The most common ignition sources in a warehouse are electrical equipment, fork lift trucks, employees, and hot work operations. Liquid storage that can produce large liquid releases (i.e., containers larger than 6.5 gal [25 L]) or storage of liquids with excess vaporization rates (i.e., boiling point below 100°F [38°C]) should have added precautions taken to prevent an ignition of a spill. Since liquid vapors are heavier than air, using hazardous area rated electrical equipment or not providing electrical equipment within 6 ft (1.8 m) of the floor would provide the needed level of ignition source control where the flammable vapors will likely be located. Careless operation of fork lift trucks creates an opportunity for an accidental release of liquid. Use of a properly rated fork lift truck would ensure the needed level of ignition control is available where the most likely source of flammable vapor generation is expected.

Control of open ignition sources such as matches, fired heating equipment, and hot work must be strictly controlled in and around areas storing ignitable liquids. Any open flame or spark has ample energy to ignite flammable vapors released by ignitable liquids. Since the vapors are heavier than air, they have the ability to flow away from the point of release. Hot work or an open flame well away from a liquid spill can ignite the spill if the vapors flow to the work area.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-0, Safeguards During Construction
Data Sheet 1-20, Protection Against Exterior Fire Exposure
Data Sheet 1-21, Fire Resistance of Building Assemblies
Data Sheet 1-29, Roof Deck Securement and Above-Deck Roofing Components
Data Sheet 2-0, Installation Guidelines for Automatic Sprinklers
Data Sheet 4-0, Special Protection Systems
Data Sheet 4-1N, Fixed Water Spray Systems for Fire Protection
Data Sheet 4-5, Portable Extinguishers
Data Sheet 4-7N, Low Expansion Foam Systems
Data Sheet 4-10, Dry Chemical Systems
Data Sheet 4-12, Foam-Water Sprinkler Systems
Data Sheet 5-8, Static Electricity
Data Sheet 5-10, Protective Grounding for Electric Power Systems and Equipment
Data Sheet 7-29, Ignitable Liquid Storage in Portable Containers
Data Sheet 7-31, Storage of Aerosol Products
Data Sheet 7-32, Ignitable Liquid Operations
Data Sheet 7-50, Compressed Gases in Cylinders
Data Sheet 7-53, Liquefied Natural Gas (LNG)
Data Sheet 7-55, Liquefied Petroleum Gas (LPG) in Stationary Installations
Data Sheet 7-78, Industrial Exhaust Systems
Data Sheet 7-83, Drainage and Containment Systems for Ignitable Liquids
Data Sheet 7-88, Ignitable Liquid Storage Tanks
Data Sheet 7-96, Printing Plants
Data Sheet 8-1, Commodity Classification

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Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*
Data Sheet 9-0/17-0, *Maintenance and Inspection*
Data Sheet 10-3, *Hot Work Management*

*Approval Guide*, an online resource of FM Approvals
FM Global Hot Work Permit System

### 4.2 NFPA


### 4.3 Other


### APPENDIX A GLOSSARY OF TERMS

**Cartoned Storage:** Containers of liquid packaged in at least a single layer of corrugated cardboard are considered cartoned storage for the purposes of this data sheet. The cardboard packaging must at least cover the bottom and two full sides of the unit. The other two sides must be at least 80% covered. The top can be open.

**Compressed Air Foam (CAF) System:** A CAF system consists of a piping system separate from the sprinkler system, an air supply, a foam concentrate supply, a water supply, a mixing system, a detection system and a control panel. To use these systems for liquid protection, they will use the same concentrate as a foam-water sprinkler system. A major advantage to this type of system is they use significantly less foam concentrate to produce very high quality foam. Testing has shown that the delivered foam is very resistant to sprinkler discharge breaking up the blanket.

**Emulsion:** An emulsion is a stable mixture of two or more immiscible liquids held in suspension by small percentages of substances called emulsifiers.

**Fire Control:** Limiting the size of a fire by distribution of water so as to decrease the heat release rate and pre-wet adjacent combustibles, while controlling ceiling gas temperatures to avoid structural damage.

**Fire Extinguishment:** The combustion process is completely stopped. As stated below in Fire Suppression, water-only ceiling sprinklers cannot extinguish a fire in liquids with a low flash point. A special protection system such as foam-water sprinkler system (See Section 2.4.1.9 and Appendix A, Foam-Water Sprinkler Systems) may be able to extinguish ignitable liquid fires.

**Fire Point:** The lowest temperature at which a liquid in an open container will give off enough vapor to ignite and continue to burn. Fire points are generally slightly higher than the open-cup flash point for a particular liquid. Liquids can have flash points without having fire points. A liquid without a fire point will not burn (e.g., 15% ethanol-water solution: closed-cup flash point 107°F [42°C], no fire point; 15% acetone-water solution: closed-cup flash point 49°F [9°C], no fire point). A liquid without a fire point is not considered to be an ignitable liquid.

**Fire Suppression:** Sharply reducing the heat release rate of a fire and preventing its regrowth by means of direct and sufficient application of water through the fire plume to the burning fuel surface. This term does not mean the fire is completely extinguished.

To date (2011), ceiling sprinkler technology cannot extinguish a low flash point liquid pool fire with water alone. Sprinklers can achieve many of the elements that define a suppressed fire (i.e., break up the fire plume, significantly reduce the heat release rate, and reduce ceiling temperatures). However, once the protection is shut down, if fuel is still present, the fire will quickly grow back to its original size. A fire involving low flash...
point liquids cannot be truly suppressed by water-based fire protection. A very high level of control is possible and, if maintained until the fuel is consumed, the fire will be extinguished.

**Flash Point:** The minimum temperature at which sufficient vapor is liberated to form a vapor-air mixture that will ignite and propagate a flame away from the ignition source (flash fire, not continuous combustion). Evaporation will take place below the flash point, but the quantity of vapor released is not sufficient to produce an ignitable vapor-air mixture. A flash point can be determined by using either a closed-cup or open-cup test apparatus. The closed-cup test will produce lower flash points than open-cup tests because it provides greater vapor containment (i.e., increases vapor accumulation). The closed-cup flash point is used to classify liquids because it is conservative (i.e., produces lowest flash point for liquid), and it represents the conditions in which most liquids are handled (i.e., most liquids are contained in closed containers or equipment).

**FM Approved:** References to “FM Approved” in this data sheet mean a product or service has satisfied the criteria for FM Approval. Refer to the Approval Guide, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

**Foam-Water Sprinkler System:** A foam-water sprinkler system consists of a closed or open head sprinkler system that is connected to a low expansion foam concentrate proportioning system designed to deliver a fixed foam concentration. The major advantage to installing a foam system is they can be added to an existing sprinkler system. Closed and open head foam-water sprinkler systems are described in Data Sheet 4-12, Foam-Water Sprinkler Systems.

**Heat of Combustion:** The amount of heat released when a unit quantity of fuel is oxidized completely to yield stable end products. The measurement is generally made in an oxygen bomb calorimeter. A similar term is the chemical heat of combustion, which represents the amount of heat released when a unit quantity of fuel is combusted in air. The chemical heat of combustion is less than the heat of combustion due to the inefficiency of the combustion process in air.

**Heat Release Rate:** The rate at which energy is released in a fire. The heat release rate is a function of the fuel’s heat of combustion, mass loss rate, and the exposed surface area.

**Ignitable Liquid:** Any liquid or liquid mixture that will burn. A liquid is defined as having the ability to burn if it has a measurable fire point. Ignitable liquids include flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn.

**Intermediate Bulk Container (IBC):** Defined by the U.S. Department of Transportation in CFR Title 49, Part 178, Subpart N, dated October 1, 1997, and the United Nations Recommendations on the Transport of Dangerous Goods, Ninth Edition, Chapter 16. The container size is limited to 793 gal (3 m³). There are no other specific requirements on the design or material of construction. All IBCs must pass the required performance-based testing designed to evaluate their resistance to leakage during transport. No existing test requirements evaluate the container’s performance when exposed to fire. The IBC category also includes the containers previously defined as portable tanks or tote tanks. Some limitations on the type of liquid storage allowed in an IBC used for transportation do exist. However, for most commonly transported ignitable liquids, there are few limitations.

In general, the maximum-size IBC used for liquid transport is approximately 660 gal (2.5 m³) due to overall package weight. More common sizes range from 250 to 330 gal (0.95 to 1.3 m³). Common IBC construction types include all-plastic self-supporting containers; plastic-supported plastic containers (plastic composite containers that consist of a rigid plastic frame supporting a plastic container); and metal-supported plastic containers (metal-plastic composite containers that consists of a metal frame supporting a plastic container). Since the only evaluation IBCs need to pass is performance-based testing, there is very little consistency in the design of IBCs produced by various manufacturers. A series of fire tests sponsored by the manufacturers clearly showed that the fire performance of a particular type of IBC could not be generalized. This is likely due to the variability of the designs.

**Composite IBC:** IBCs consisting of a blow-molded plastic bottle enclosed within a steel cage.

**Plastic IBC:** IBC with a plastic bottle surrounded by a plastic frame.

**Bag-In-Box IBC:** IBC consisting of a plastic bag inside a corrugated box.

**Liquid:** A material that does not have a defined shape at room temperature unless it is stored in a container. These materials flow freely when released. (e.g., water, honey, heptane).

**Non-Ignitable Liquid:** A liquid that does not burn.
Relieving-Style Container: A relieving-style container will release excess internal pressure without a significant release of the stored liquid when exposed to a fire. The pressure relief prevents the violent rupture of the container. It is also critical that the pressure relief does not allow significant liquid release. At this point in time (2011), only metal portable tanks (now included in the general container category of IBCs) are specifically listed or FM Approved to vent under fire exposure. The determination for all other container types is qualitative.

1. Some examples of relieving-style containers are:
   - A metal 55 gal (230 L) drum fitted with plastic plugs in both the 2 in. (5.1 cm) and 3/4 in. (1.9 cm) openings in the top of the drum. Testing by FM Global and others using nylon and polyethylene plugs has shown that the plug will fail when exposed to a fire and prevent a significant pressure buildup in the drum as well as maintain the overall drum integrity. Full-scale fire tests on metal drums filled with heptane and fitted with plastic plugs has shown that the relieving action will allow for greater palletized storage heights.
   - A metal 5 gal (25 L) tight head pail (i.e., top and bottom are permanently attached to sides) with plastic pour spout. Most tight head 5 gal (25 L) containers are relieving-style. Testing has shown that the plastic pour spout will melt and allow the container to vent and prevent the full release of the stored liquid.
   - A metal 5 gal (25 L) lug head pail (i.e., top is held in place by friction and lug tabs on cover, similar to a large paint can) with plastic pour spout. Same performance as the tight head container.
   - A metal 1 gal (4 L) F-style (rectangular) can with either a plastic spout or a soldered metal spout. Both spout arrangements will fail in a fire and allow internal pressure to vent while preventing the release of the liquid.
   - A metal 1 gal (4 L) friction lid can (e.g., circular paint cans). The friction lid will pop off when exposed to fire. In many cases, the lid will only move slightly, allowing pressure relief without significant liquid release. In some cases, the lids move away from the container allowing liquid to spray out during the release and sprinkler water to enter the can and displace the stored liquid. The small can size minimizes this negative performance.

   Metal IBCs that meet DOT/UN rules.

2. Some examples of non-relieving-style containers or containers that are not acceptable as relieving-style are:
   - A metal 55 gal (230 L) drum fitted with metal plugs in both the 2 in. (5.1 cm) and 3/4 in. (1.9 cm) openings in the top of the drum. This container will not release internal pressure early in a fire. The end result of a sealed drum exposed to fire is the violent failure of the container.
   - A metal 55 gal (230 L) drum fitted with a plastic plug in an opening located in the side of the drum or a plastic container of any size. Both container types will vent any pressure buildup; however, they will also release the stored liquid, resulting in an uncontrolled fire.
   - A metal 5 gal (25 L) tight head pail (i.e., top and bottom are permanently attached to sides) with metal caps over opening. This container will not vent pressure buildup early in a fire.
   - A metal 5 gal (25 L) lug head pail (i.e., top is held in place by friction and lug tabs on cover, similar to a large paint can) with metal caps over the opening. The top of this type of container will vent pressure buildup similar to the 1 gal (4 L) paint can. However, the lid tends to release at a higher pressure and the venting of the lid results in a large quantity of liquid release. Also, once open, sprinkler water will enter the container and displace the stored liquid. The quick response sprinkler-based fire protection scheme for metal containers could fail to control the fire if several 5 gal (25 L) containers release their contents.
   - A metal 1 gal (4 L) F-style (rectangular) can with crimped-on metal spout. These containers have failed violently during full-scale fire tests.

Semi-solid: A material that has a defined shape at room temperature without containment, but can be forced to flow with pressure. (e.g., butter, paste ink, gels).

Solid: A material that has a defined shape at room temperature and cannot be forced to flow with pressure. (e.g., wood, plastic, glass, wax)

Specific Gravity: The ratio of the weight of a substance to the weight of the same volume of another substance. The specific gravity for ignitable liquids is provided using water as a basis. Specific gravities less than 1 indicate the liquid is lighter than, and will float on top of, water. Conversely, specific gravities greater than 1
indicate the liquid will sink in water. This information permits a determination of what effect water will have on an ignitable liquid fire. Liquids heavier than water will sink, indicating water would extinguish a fire involving this liquid (cover liquid and smother fire). Liquids lighter than water will float, indicating the fire would not be extinguished but could be spread by water if adequate drainage is not provided.

**Stable Liquid:** A liquid that does not self-react or polymerize.

**Uncartoned Storage:** Containers of liquid that are arranged on pallets without cardboard boxes are considered uncartonized storage for the purposes of this data sheet. This type of storage usually consists of containers arranged on trays or sheets layered on a pallet and held in place with shrink-wrapping. Uncartonized storage also applies to any storage that does not meet the definition of cartoned storage.

**Unstable Liquid:** A liquid that, in the pure state or as commercially produced or transported, will vigorously polymerize, decompose, undergo condensation reaction, or become self-reactive under condition of shock, pressure or temperature.

**Vapor Density:** The weight of a volume of pure vapor or gas (with no air present) compared to the weight of an equal volume of dry air at the same temperature and pressure. It is calculated as the ratio of the molecular weight of the gas to the average molecular weight of air. 29. A vapor density figure less than 1 indicates the vapor is lighter than air. A figure greater than 1 indicates the vapor is heavier than air.

Ignitable liquids produce vapor that is heavier than air. The vapor will collect at floor level and exhibit fluid properties (i.e., it will flow to low points and accumulate). Flammable vapor, if not removed by ventilation, can flow to an ignition source and flash back to the vapor source.

**Wall Construction Categories:**

- **Combustible:** A wall made of any combustible material, any metal-faced plastic-insulated sandwich panels that are not FM Approved, and any wall with single-pane annealed (not tempered) glass windows.

- **Noncombustible:** Materials include FM Approved Class 1 insulated, steel or aluminum-faced sandwich panels with thermostatic plastic insulation; exterior insulation and finish system (EIFS) assemblies having noncombustible insulation and gypsum board sheathing; and aluminum or steel panels that are uninsulated or insulated with noncombustible insulation such as glass fiber, mineral wool, or expanded glass. It also includes cementitious panels or shingles over steel or wood. Any windows should be multi-pane or tempered glass.

- **Fire Rated:** The wall should meet the required fire rating per FM Global Data Sheet 1-21, *Fire Resistance of Building Assemblies*. Any openings should be protected with a comparably fire-rated door. Any windows should be fire-rated to match the rating of the wall.

**Water-miscible:** A water-miscible liquid mixes in all proportions with water. When water-miscible ignitable liquids are mixed with water, a homogenous solution is formed. The flash point, fire point, heat of combustion, and heat release rate of the solution will be different from the pure ignitable liquid. The flash point and fire point of the solution will increase as the water concentration increases. At a certain water concentration (which varies for different ignitable liquids), the fire point will no longer exist and the solution will no longer present a fire hazard (e.g., 15% ethyl alcohol in water, 15% acetone in water).

**APPENDIX B DOCUMENT REVISION HISTORY**

April 2020. Interim revision. Minor editorial changes were made.

January 2018. Interim revision. Lowered the flashpoint threshold of very high flashpoint liquids from 500°F (260°C) to 450°F (232°C).

July 2014. Interim revision. The following changes were made:

- A. Added new protection options for palletized storage of Group 3 water-miscible liquid in 59 oz (1.75 L) glass or plastic bottles for the following storage and roof height combinations:
  - 17 ft (5.2 m) (max) of storage in a 30 ft (9 m) building
  - 17 ft (5.2 m) (max) of storage in a 40 ft (12 m) building
  - 5 ft (1.5 m) of storage in a 40 ft (12 m) building
B. Added a new protection option for rack storage of Group 3 water-miscible liquid in 59 oz (1.75 L) glass or plastic bottles that does not use a solid barrier and is stored to unlimited heights in unlimited-height buildings.

C. Added a new protection option for rack storage of Group 1 water-miscible liquid in 60 gal (230 L) plastic drums for storage heights up to 30 ft (9 m) in 45 ft (13.7 m) high buildings.

April 2012. Minor editorial changes were done for this revision.

January 2012. The following changes were made for this revision:

A. Replaced references to “flammable” and “combustible” liquids with “ignitable” liquids throughout the document.

B. Modified formatting, changed rearranged tables, and eliminated inconsistencies as follows:
   1. Rearranged the document to align with the current data sheet format.
   2. Renumbered, edited, and reformatted all tables to improve consistency, clarity, and alignment with the pressure/number of sprinklers approach in Data Sheet 8-9.
   3. Added definitions of liquid, solid, semi-solid, stable liquid, and unstable liquid.
   4. Moved semi-solid liquid evaluation criteria from Data Sheet 8-1 to this document and simplified the criteria.
   5. Clearly stated that ignitable liquid storage cannot be mixed with flammable gas or oxidizers.

C. Revised location and construction as follows:
   1. Eliminated space separation figures for outdoor storage and aligned the approach with Data Sheet 7-88 and Data Sheet 1-22 criteria.
   2. Revised the drainage and containment table to include all liquids and containers covered by this data sheet (now Tables 3a and 3b).
   3. Revised/clarified the drainage and containment recommendations to simplify the criteria, identify reduced criteria for liquids with a specific gravity greater than one, and add containment requirements for high flash point liquids and alcohol in composite IBCs protected in accordance with Table 13.
   4. Created a single location table for all liquids and containers covered by this data sheet.
   5. Included compressed air foam (CAF) protection systems as an option for lack of emergency drainage, and eliminated gaseous special protection systems as an option.
   6. Added more guidance on the use and location of FM Approved ignitable liquids cabinets.
   7. Added an allowance for locating an FM Approved prefabricated ignitable liquid storage buildings (PILSBs) within a building.

D. Revised protection options as follows:
   1. Provided an evaluation of the fire hazard created by specific liquids such as glycols, silicone fluids and silicone-water emulsions, PMDI/Polyol, butterfat, and unsaturated polyester resins.
   2. Based on the results of recent fire tests, added guidance for protecting liquids with flash points at or above 500°F (260°C) in containers larger than 40 gal (150 L). Included guidance for composite and bag-in-box IBCs.
   3. Added new protection criteria for 3-high palletized empty composite IBCs with plastic, wood, or steel pallets.
   4. Reworded the recommendation for storing empty containers. (NOTE: There is no technical change from the previous standard. The recommendation was simply rewritten to make it easier to understand.)
   5. Removed the allowance for storing high flash point liquids in larger containers in general purpose warehouses because providing drainage is not considered practical.
6. Revised in-rack sprinkler design criteria to be based on a flow instead of a pressure. Also included the use of larger orifice sprinklers, which will allow for lower in-rack sprinkler discharge pressures. A minimum discharge pressure of 10 psi (0.7 bar) has been defined.

7. Provided protection criteria for high flash point (≥200°F [93°C]) liquids and alcohols in composite IBCs in racks.

8. Changed all ceiling sprinkler recommendations to provide a K11.2 (K160) or larger sprinkler in accordance with the requirements of NFPA 13, Standard for the Installation of Sprinkler Systems.

9. Added an option for protecting multiple-row rack storage of steel drums.

10. Revised protection criteria in Table 4 (previously Table 6) for two-high palletized metal IBCs containing liquids with a flash point at or above 200°F (93°C).

11. Based on the results of full-scale fire tests, eliminated standard response protection criteria for palletized storage of uncartoned small metal containers (6.5 gal [25 L] or less) regardless of liquid type.

12. Added a new Table 5 for rack storage of metal IBCs.

13. Provided a protection option for small metal containers (6.5 gal [25 L] or less) using Scheme A.

14. Provided protection for rack storage of low flash point liquids in up to 1 gal (4 L) plastic containers.

15. Added protection criteria for liquids with a flash point below 200°F (93°C) in 0.5 oz (15 ml) and 2 oz (60 ml) plastic containers.

16. Added protection criteria for Group 1 water-miscible liquids in 6 oz (180 ml), 6.5 gal (25 L), and 60 gal (230 L) plastic containers.

17. Revised protection for palletized liquids with a flash point above 450°F (232°C) in Table 17 to better reflect full-scale fire testing:
   - a) Increased standard response sprinkler protection for 15 ft (4.6 m) high storage in a 30 ft (9.1 m) building for containers up to 6.5 gal (25 L).
   - b) Increased standard response protection for 5 ft (1.5 m) high storage in a 30 ft (9.1 m) building for containers up to 6.5 gal (25 L).
   - c) Added protection for 20 ft (6 m) high storage in a 30 ft (9.1 m) building for 1 gal (4 L) containers.
   - d) Added protection for 15 ft (4.6 m) high storage in a 30 ft (9.1 m) building for 48 oz (1.4 L) containers.

18. Added new protection for rack storage of cartoned cooking oils in 35 ft (11 m) high racks in a 40 ft (12 m) building.

19. Revised protection for palletized water-miscible liquids in Table 18:
   - a) Glass and plastic bottles are differentiated due to the very poor performance of glass.
   - b) Group 3 in glass bottles has been severely limited due to a lack of successful testing.
   - c) Group 4 protection has been modified. One option was removed (specific application sprinkler protection), and the protection for standard response sprinklers was increased and the sprinkler temperature was changed to ordinary.

20. Revised in-rack protection requirements for steel drum storage of liquids with a flash point greater than or equal to 200°F (93°C) to align with in-rack arrangements for lower flash point liquid storage.

21. Reduced the hose stream requirement to 250 gpm (950 L/min) for certain cases with Scheme A protection criteria.

June 2009. Reference to Data Sheet 7-53, Liquefied Natural Gas (LNG), was deleted.

September 2004. Metric values in figures for fire protection Scheme A were corrected.

May 2004. Eliminated the exclusion for plastic or glass bottles that are 2 oz (60 ml) or less in size. Recent full-scale fire tests have demonstrated that even small plastic or glass bottles that are filled with an ignitable liquid can produce a severe fire hazard. New protection criteria has been added in Table 16a.

September 2003. The following changes have been made for this revision:
1. Provided information on the FM Approved fusible plugs for relieving-style drums.

2. Revised the title of Table 8 to eliminate the lower container size limit of 6.5 gal (25 L). The protection criteria in this table can be applied to smaller containers.

3. Revised protection criteria in Table 10 for rack storage of small metal containers. Provided criteria for high temperature ceiling sprinklers.

September 2002. Fire protection tables have been revised to be consistent with the new sprinkler approval categories.

May 2000. This document has been reorganized to provide a consistent format. In addition to the reformatting the following technical changes have been made:

1. New fire protection for products with less than or equal to 50% water-miscible liquid have been added. All of the water-miscible liquid fire protection criteria for rack storage have been incorporated into two new tables.

2. Space separation distances between low value unprotected ignitable liquid buildings and main buildings has been clarified.

3. ELO sprinklers have been expanded to include all control mode, area density spray sprinklers with a K-factor greater than or equal to K11.2 (K160).

4. Clarified use of ignitable liquid storage cabinets in warehouse areas.

September 1999. Minor Technical Revisions

May 1999. The document represents a complete rewrite of this data sheet. All previous recommendations were re-evaluated. Significant changes in the fire protection recommendations have been incorporated. The recommended criteria better reflect recent test results and have eliminated a number of inconsistencies in the old criteria. Fire protection design drawings have been provided to help clarify recommendations. The majority of the fire protection criteria is provided in tabular format.

**APPENDIX C NFPA STANDARD**

The 2008 edition of NFPA 30, *Flammable and Combustible Liquids Code*, covers ignitable liquid storage, use, piping and tanks. The storage chapters (9, 10, 11, 12, 13, 14, 15, and 16) share many similarities with this standard, however, do provide allowable minimum storage quantities that do not require adequate fire protection. Unfortunately, these minimum quantities are still sufficient to cause an uncontrolled fire. The majority of the fire protection is similar to the protection provided in this standard.

**APPENDIX D JOB AIDS**

**D.1 Abbreviations Used in Fire Protection Tables**

- QR = Quick response sprinkler
- SR = Standard response sprinkler
- NA = Not applicable
- DRR = Double-row rack, ≤ 9 ft (2.7 m) wide
- Ordinary = Nominal 165°F (74°C) temperature rating
- High = Nominal 286°F (141°C) temperature rating

**D.2 Fire Protection Illustrations**

**D.2.1 In-Rack Layouts**

Figures 3 through 11 show in-rack layouts.
Fig. 3a. Double row rack sprinkler layout - drum protection scheme

△, ●, X = FM Approved Rack Storage Sprinkler, LO, QR
Fig. 3b. Double row rack sprinkler layout - drum protection scheme

△, × = FM Approved Rack Storage Sprinkler, LO, QR
Fig. 3c-1. Multiple row rack sprinkler layout - drum protection scheme

▲, ●, X = FM Approved Rack Storage Sprinkler

2 to 3 Drums and 10 - 15 ft. (3 - 4.6 m) maximum

2 Drums and 10 ft. (3 m) maximum

2 Drums and 10 ft. (3 m) maximum

1 Drum and 5 ft. (1.4 m) maximum
Fig. 3c-2. Multiple row rack sprinkler layout - drum protection scheme

Plan View
- Second tier face sprinklers
- All tiers longitudinal flue sprinklers

▲ ●, X = FM Approved Rack Storage Sprinkler

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Fig. 3d. Double row rack sprinkler layout - drum protection scheme

●, X = FM Approved Rack Storage Sprinkler, LO, QR
Fig. 3e. Double row rack sprinkler layout - drum protection scheme

X = FM Approved Rack Storage Sprinkler, LO, QR
Fig. 3f. Double row rack sprinkler layout - drum protection scheme
Fig. 3g. Double row rack sprinkler layout - drum protection scheme

8 ft. (2.4 m) Maximum
9 ft. (2.7 m) Maximum

6 in. (15 cm) Minimum

Provide one level of in-rack sprinklers below top tier of storage regardless of rack height

× = FM Approved Rack Storage Sprinkler, LO, QR
Fig. 3h. Double row rack sprinkler layout - IBC protection scheme
Fig. 4a. Single row rack sprinkler layout - small metal containers
Fig. 4b. Double row rack sprinkler layout - small metal containers
Fig. 4c. Multiple row rack sprinkler layout - small metal containers
Fig. 4d. Multiple row rack sprinkler layout - small metal containers

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Fig. 5a. Single row rack sprinkler layout - small metal containers
Fig. 5b. Double row rack sprinkler layout - small metal containers
Fig. 6a. Single row rack sprinkler layout - small metal containers
Fig. 6b. Double row rack sprinkler layout - small metal containers
Fig. 7a. Single row rack sprinkler layout - water-miscible liquids in small metal containers
Fig. 7b. Double row rack sprinkler layout - water-miscible liquids in small metal containers
Fig. 7c. Multiple row rack sprinkler layout - water-miscible liquids in small metal containers
**Fig. 7d. Multiple row rack sprinkler layout - water-miscible liquids in small metal containers**

Plan View

●, X = FM Approved Rack Storage Sprinkler, LO, QR

*Fig. 7d. Multiple row rack sprinkler layout - water-miscible liquids in small metal containers*
Fig. 8a. Double row rack sprinkler layout - quick response sprinklers protection scheme
Fig. 8b. Double row rack sprinkler layout - quick response sprinklers protection scheme
Fig. 8c. Double row rack sprinkler layout - quick response sprinklers protection scheme
Fig. 8d. Double row rack sprinkler layout - quick response sprinklers protection scheme

Plan View

Elevation View

X = FM Approved Rack Storage Sprinkler, LO, QR

9 ft. (2.7 m) Maximum

10 ft. (3 m) Maximum

15 ft. (4.6 m) Maximum
Fig. 8e. Multiple row rack sprinkler layout - quick response sprinklers protection scheme

Plan View

●, X = FM Approved Rack Storage Sprinkler, LO, QR

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Fig. 8f. Multiple row rack sprinkler layout - quick response sprinklers protection scheme

●, X = FM Approved Rack Storage Sprinkler, LO, QR
Fig. 8g. Multiple row rack sprinkler layout - quick response sprinklers protection scheme
Fig. 8h. Multiple row rack sprinkler layout - quick response sprinklers protection scheme
Plan View

\(\times\) = FM Approved Rack Storage Sprinkler, LO, QR

*Fig. 8i. Multiple row rack sprinkler layout - quick response sprinklers protection scheme*
Fig. 8j. Multiple row rack sprinkler layout - quick response sprinklers protection scheme

=X = FM Approved Rack Storage Sprinkler, LO, QR
Plan View

●, X = FM Approved Rack Storage Sprinkler, LO, QR

*Fig. 8k. Multiple row rack sprinkler layout - quick response sprinklers protection scheme*
Fig. 81. Multiple row rack sprinkler layout - quick response sprinklers protection scheme

○, X = FM Approved Rack Storage Sprinkler, LO, QR
Fig. 9a. Single Row Rack Storage of Group 4 Water-miscible Liquids

Plan View

Elevation View

● = In-Rack Sprinklers

2/3 to 3/4 Rack Height

8 ft. (2.4 m) Maximum

5 ft. (1.4 m)

25 ft. (7.6 m) Maximum

1/4 to 1/3 Rack Height
Fig. 9b. Double Rack Storage of Group 4 Water-miscible Liquids I

- **Plan View**:
  - 8 ft. (2.4 m) spacing
  - Maximum height: 9 ft. (2.7 m)

- **Elevation View**: 25 ft. (7.6 m) maximum height

- **In-Rack Sprinklers**:
  - 2/3 to 3/4 Rack Height
  - 1/4 to 1/3 Rack Height

- **Note**: ● = In-Rack Sprinklers

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Fig. 10a. Single Row Rack Storage of Group 4 Water-miscible Liquids

Plan View

15 ft. (4.6 m) to 25 ft. (7.6 m)
1/2 to 2/3 Rack Height

Elevation View

△ = In-Rack Sprinklers
Fig. 10b. Double Row Rack Storage of Group 4 Water-miscible Liquids

▲ = In-Rack Sprinklers
Fig. 11. Double Row Rack Storage of Group 3 Water-miscible Liquids

Plan View

Deflector a Minimum of 6 in. (15 cm) Above Tops of Storage

Elevation View

△ = In-Rack Sprinklers

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D.2.2 Fire Protection Schemes

D.2.2.1 Fire Protection Scheme A

A. Provide plywood (minimum 3/8 in. [1 cm]) or sheet metal (minimum 22 ga. [0.7 mm]) barriers and in-rack sprinklers installed in accordance with Figures 12a, 12b, 12c, and 12d depending on the allowed rack type for the storage. Use a maximum vertical spacing of 12 ft (3.7 m) between barriers.

*Note:* No ignitable liquid storage is permitted above the top barrier level.

B. Install FM Approved K8.0 (K115) or K11.2 (K160), 165°F (74°C) rated, quick response in-rack sprinklers below each barrier level. Design the in-rack sprinklers to provide a minimum flow of 57 gpm (216 L/min) out of the hydraulically most remote six (6) sprinklers (three on two lines) if one barrier level, or the most remote eight (8) sprinklers (four on two lines) if two or more barrier levels are provided.

C. For liquids with a flash point at or above 200°F (93°C) and water-miscible liquids in containers of 1 gal (4 L) or less, provide the following:

1. If there are adjacent bays of rack arrays not dedicated to liquid storage, extend the barrier and in-rack sprinkler protection at least one rack bay, approximately 8 ft (2.4 m) beyond the liquid storage.

2. Ceiling sprinkler demand does not need to be included in the hydraulic calculations for in-rack sprinklers. Calculate the water demand at point of supply separately for in-rack and ceiling sprinklers. Provide a 250 gpm (946 L/min) hose stream allowance in the hydraulic calculations for the in-rack sprinkler protection. Provide the combined fire protection water demand for a 1-hour duration.

3. Design ceiling sprinklers to protect the surrounding occupancy. A minimum ceiling sprinkler design of not less than 7 psi (0.5 bar) using twenty (20) K8.0 (K115) sprinklers is required. If the liquid storage does not extend to the full height of the rack, protect the other commodities stored above the barrier in accordance with appropriate data sheets as if the entire rack height was filled with that commodity. If in-rack sprinklers are required for the other commodities, each level of barrier and in-rack sprinklers can be given credit as a level of in-rack sprinklers.

D. For water-miscible liquids in containers of 6.5 gal (25 L) or less; or metal containers of 6.5 gal (25 L) or less with any ignitable liquid, provide the following:

1. If all racks in the cutoff room are not protected with the same level of protection, extend the barrier and in-rack sprinkler protection at least two rack bays, approximately 16 ft (4.9 m) beyond the liquid storage and to racks on each side of the storage.

2. Balance the ceiling sprinkler demand provided in the appropriate protection table and the in-rack sprinkler demand at the point of connection. Provide a 500 gpm (1890 L/min) hose stream allowance. Provide the fire protection water demand for a 1-hour duration.

3. Design ceiling sprinklers in accordance with the appropriate protection table.
Fig. 12a. Single row rack sprinkler layout - fire protection scheme A
Fig. 12b. Single row rack sprinkler layout - fire protection scheme A
Fig. 12c. Double row rack sprinkler layout - fire protection scheme A
Fig. 12d. Multiple row rack sprinkler layout - fire protection scheme A
D.2.2.2 Fire Protection Scheme B

A. Install in-rack sprinklers in accordance with Figures 13a, 13b, 13c, and 13d. Stagger face-sprinklers for the double-row racks vertically.

B. Install FM Approved K8.0 (K115) or K11.2 (K160), 165°F (74°C) rated, quick response in-rack sprinklers. Design the in-rack sprinklers to provide a minimum flow of 30 gpm (114 L/min) out of the hydraulically most remote 8 sprinklers (4 on two lines) if one level of in-rack sprinklers is provided, or the most remote 14 sprinklers (7 on two levels) if two or more levels are provided.

C. If there are adjacent bays of rack storage not dedicated to liquid storage, extend the in-rack sprinkler protection by at least one rack bay, approximately 8 ft (2.4 m) beyond the liquid storage.

D. Balance the ceiling and in-rack demands at the point of connection to the water supply. Provide a 500 gpm (1890 L/min) hose stream allowance in the hydraulic calculations. Provide the combined fire protection water demand for a 1-hour duration.
Fig. 13a. Single row rack sprinkler layout - fire protection scheme B
Fig. 13b. Single row rack sprinkler layout - fire protection scheme B
Fig. 13c. Double row rack sprinkler layout - fire protection scheme B

- Longitudinal Flue Sprinkler
- Face Sprinkler

Plan View

- 8 - 10 ft. (2.4 - 3 m) spacing
- 4 - 5 ft. (1.2 - 1.5 m) spacing

Elevation View

- 9 ft. (2.7 m) maximum height
- 5 ft. (1.4 m) maximum height
- 10 ft. (3 m) to 12 ft. (3.7 m) storage height

Deflector a minimum of 6 in. (15 cm) above top of storage

Page 102

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Fig. 13d. Multiple row rack sprinkler layout - fire protection scheme B
D.2.2.3 Fire Protection Scheme C

A. Install in-rack sprinklers in accordance with Figures 14a, 14b, and 14c.

B. Install FM Approved K8.0 (K115) or K11.2 (K160), 165°F (74°C) rated, quick response in-rack sprinklers. Design the in-rack sprinklers to provide a minimum flow of 30 gpm (114 L/min) out of the hydraulically most remote eight sprinklers if one level of in-rack sprinklers is provided, or the most remote 14 sprinklers (7 on two levels) if two or more levels are provided.

C. If there are adjacent bays of rack storage not dedicated to liquid storage, extend the in-rack sprinkler protection by at least one rack bay, approximately 8 ft (2.4 m) beyond the liquid storage.

D. Balance the ceiling and in-rack demands at the point of connection to the water supply. Provide a 500 gpm (1890 L/min) hose stream allowance in the hydraulic calculations. Provide the combined fire protection water demand for a 1-hour duration.

E. For cartoned 48 oz (1.4 l) containers stored in 35 ft (10.7 m) high double or single row racks in a 40 ft (12.2 m) high building, a single level of in-racks sprinklers located at approximately the 15 ft (4.6 m) vertical level with the horizontal spacing shown in Figures 14a or 14c maybe used. Design the in-rack sprinklers in accordance with item B above.
Fig. 14a. Single row rack sprinkler layout - fire protection scheme C
Fig. 14b. Single row rack sprinkler layout - fire protection scheme C

Deflector a Minimum of 6 in. (15 cm) Above Top of Storage

In-Rack Sprinkler
Fig. 14c. Double row rack sprinkler layout - fire protection scheme C

Deflector a Minimum of 6 in. (15 cm) Above Top of Storage

Plan View

Elevation View

△ In-Rack Sprinkler

9 ft. (2.7 m) Maximum

5 ft. (1.4 m) Maximum

10 ft. (3 m) Maximum

4 - 5 ft. (1.2 - 1.5 m) Maximum

IGNITABLE LIQUID STORAGE IN PORTABLE CONTAINERS 7-29
FM Global Property Loss Prevention Data Sheets

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D.2.2.4 Fire Protection Scheme D

A. Provide plywood (minimum 3/8 in. [1 cm]) or sheet metal (minimum 22 ga. [0.7 mm]) barriers and in-rack sprinklers installed in accordance with Figures 15a, 15b, or 15c depending on the rack type. Use a maximum vertical barrier spacing of 6 ft (1.8 m).

Note: No ignitable liquid storage is permitted above the top barrier level.

B. Install FM Approved K8.0 (K115) or K11.2 (K160), 165°F (74°C) rated, quick response in-rack sprinklers below each barrier level. Design the in-rack sprinklers based on the container size and liquid type provided below.

C. For liquids with a flash point at or above 200°F (93°C) and alcohols in composite IBCs, provide the following:

   1. This protection approach has only been tested for rack storage. Testing on palletized storage arrays has shown that composite IBCs cannot be adequately protected using ceiling-only sprinkler protection. Since pallet loads are transported into and out of racks and a fire involving even a single IBC could damage the building, only use this approach in well-cutoff rooms.

   2. Limit storage to the bottom tier of the rack.

   3. Design the in-rack sprinklers to provide a minimum flow of 60 gpm (227 L/min) out of the hydraulically most remote eight (8) sprinklers (four on two lines). If there are additional barrier levels above the first tier (e.g., protecting smaller containers with Scheme A), design the total in-rack system to supply the most remote ten (10) sprinklers (five on two lines).

   4. Protect all racks in the cutoff room with the same level of protection. Arrange the room to ensure there will not be any on-floor storage. Storage is permitted above the first rack tier but is limited to products that can be protected by Scheme A. Protection above the first tier can either continue with Scheme D for the full height of the rack or use Scheme A for the full height of the rack.

   5. Balance the ceiling sprinkler demand and the in-rack sprinkler demand at the point of connection. Provide a 500 gpm (1890 L/min) hose stream allowance. Provide the fire protection water demand for a 1-hour duration.

D. For water-miscible liquids in plastic containers of 60 gal (230 L) or less, provide the following:

   1. This protection approach has only been tested for rack storage. It is unknown if palletized storage can be protected with a ceiling-based sprinkler system. Since pallet loads are transported into and out of racks and a fire involving even a single pallet load could damage the building, this approach should only be used in well-cutoff rooms.

   2. Design the in-rack sprinklers to provide a minimum flow of 45 gpm (170 L/min) out of the hydraulically most remote eight (8) sprinklers (four on two lines) if one barrier level, or the most remote five (5) sprinklers per tier up to twenty (20) if two or more barrier levels are provided.

   3. Protect all racks in the cutoff room with the same level of protection. Arrange the room to ensure there will not be any on-floor storage.

   4. Balance the ceiling sprinkler demand and the in-rack sprinkler demand at the point of connection. Provide a 500 gpm (1890 L/min) hose stream allowance. Provide the fire protection water demand for a 1-hour duration.

E. For liquids with a flash point below 200°F (93°C) in plastic containers of 1 gal (4 L) or less, provide the following:

   1. This protection approach has only been tested for rack storage. It is unknown if palletized storage can be protected with a ceiling-based foam-water sprinkler system. Since pallet loads are transported into and out of racks and a fire involving even a single pallet load could damage the building, this approach should only be used in well-cutoff rooms.

   2. Design the in-rack sprinklers to provide a minimum flow of 60 gpm (227 L/min) out of the hydraulically most remote six (6) sprinklers (three on two lines) if one barrier level, or the most remote eight (8) sprinklers (four on two lines) if two or more barrier levels are provided.
3. Protect all racks in the cutoff room with the same level of protection. Arrange the room to ensure there will not be any on-floor storage. Storage is permitted above the fourth rack tier but is limited to products that can be protected by Scheme A. Protection above the first tier can either continue with Scheme D for the full height of the rack or use Scheme A for the full height of the rack.

4. Balance the ceiling sprinkler demand and the in-rack sprinkler demand at the point of connection. Provide a 500 gpm (1890 L/min) hose stream allowance. Provide the fire protection water demand for a 1-hour duration. For containers less than 1 gal (4 L), ceiling and in-rack sprinkler designs do not need to be balanced.

5. Provide an FM Approved foam-water sprinkler system for the ceiling and in-rack protection.

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Fig. 15a. Single row rack sprinkler layout - fire protection scheme D.
Fig. 15b. Single row rack sprinkler layout - fire protection scheme D
Fig. 15c. Double row rack sprinkler layout - fire protection scheme D
D.2.2.5 Fire Protection Scheme E

A. Install in-rack sprinklers on 20 ft (6 m) vertical increments in accordance with Figures 16a and 16b. Repeat the in-rack pattern shown in Figure 16b from rack face to rack face for multiple row racks.

B. Install FM Approved K8.0 (115) or K11.2 (160), 165°F (74°C) rated, quick response, in-rack sprinklers.

C. Design the in-rack sprinklers to provide a minimum flow of 30 gpm (110 L/min) out of the hydraulically most remote:
   1. Six in-rack sprinklers on 1 level if one level of in-racks (6 total).
   2. Six in-rack sprinklers on 2 levels if two level of in-racks (12 total).
   3. Six in-rack sprinklers on 3 levels if three or more levels of in-racks (18 total).

D. If there are adjacent bays of rack storage not dedicated to liquid storage, extend the in-rack sprinkler protection by at least one rack bay, approximately 8 ft (2.4 m) beyond the liquid storage.

E. Balance the ceiling and in-rack demands at the point of connection to the water supply. Provide a 500 gpm (1890 L/min) hose stream allowance in the hydraulic calculations. Provide the combined fire protection water demand for a 1-hour duration.

Fig. 16a. Single row rack sprinkler layout - fire protection scheme E.
Fig. 16b. Double row rack sprinkler layout - fire protection scheme E
[For multi-row racks continue the same pattern in this figure through the rack]