FIRE HAZARDS OF FLAMMABLE LIQUIDS IN SMALL CONTAINERS

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Standards of fire protection for metal drums and smaller metal containers of flammable liquids have been well defined and have proved dependable. However,there has been a recent trend in industry to change from metal to plastic containers for quantities of flammable liquids less than 20 litres. Fire tests by Factory Mutual Research have shown that the use of plastic containers can greatly increase the fire hazard when in a storage situation. Recommendations for segregation,safe storage arrangements and protection are presented.

(Fire protection,flammable liquids,plastic containers)

INTRODUCTION

Until recently,the fire and explosion hazards associated with storage of 205 litre drums of flammable liquids and smaller containers were thought to be well understood. Extensive testing[1] in the 1950's-1960's and industry loss experience made us confident that the fire protection for flammable liquids (classified by flash point and boiling point - see Appendix 1) in various storage arrays was sound and dependable.

A lesson of recent years is that as industry changes its practices,the hazards change also. Aerosol products are a good example. As the use of aerosol packaged products became increasingly common,environmental pressures in the U.S.A. forced a ban on the use of non-flammable chlorofluorocarbons as propellants. Replacement propellants commonly included highly flammable propane and butane but also other gases such as nitrogen, carbon dioxide and nitrous oxide. Industry was concerned about the possible increased fire hazard. This concern and several fire losses[2] involving aerosol products prompted an extensive text programme by Factory Mutual Research Corporation (FMRC).

Surprsingly, the research programme showed that the use of a flammable propellant added little to the overall fire hazard of the aerosol product. It was discovered that the flammability of the base product is the major consideration.[3,4] With the co-operation of manufacturers in the U.S.A., several products have been classified into 3 hazard levels: Level I, Level II and Level III.

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Level	Base Product (% W/W) (Applies to flammable or non-flammable propellant)	Typical Generic Examples
I	Maximum 25% water miscible or non-miscible flammable products (i.e. 75-100% non-flammable products).	Oven cleaners,shaving creams,air fresheners, spray starches.
II	25% to 100% water miscible flammable products,25 to 55% non-miscible flammable products (remaining 45 to 75% is non-flammable product).	Deodorants (except oil based),hairsprays,disinfectants,antistatic sprays.
III	Greater than 55% non water miscible flammable product.	Furniture polish (some), lubricants,paints,automotive products,oil based anti-perspirants.

Another,more recent,industry change that is giving us concern is the use of plastic containers instead of metal containers for small quantities of flammable liquids. These plastic containers are generally smaller than 20 litres in volume,usually 5 litres or less,and are being used with increasing frequency to package such products as charcoal lighter fluid,methylated spirits, paint thinner and hair spray. Industry has found that these lightweight containers reduce shipping costs and are cheaper to manufacturer.

Preliminary fire tests by FMRC[5] have shown that plastic containers melt or burn through quickly,releasing their contents to create a pool fire that can quickly spread over a wide area. These recent tests are discussed below and form the subject of this paper.

FIRE TEST RESULTS

The following five tests were conducted at the 9.1m test site of the Factory Mutual Test Centre at West Gloucester,Rhode Island,U.S.A. Appendix 2 summarizes the results. Ignition of the products was by a standard kerosene FM ignitor.

Petroleum Liquids

Test No. 1

This test was conducted with a single pallet load of commercial paint thinner (closed cup flash point 40C) in polyethylene,3.8 litre containers.

The pallet load consisted of 180-3.8 litre containers packaged in cardboard boxes,3 containers to a box. Ninety-six 12.7mm orifice,138 C rated sprinklers were installed on a 9.3sqm spacing per head. The ceiling sprinkler discharge pressure was 2.0 bars.

The fire opened 42 sprinklers. The gas temperature at ceiling level peaked at 1246 C,roof steel exceeded 538 C (the temperature at which building steel will weaken) for 3½ minutes. (See Appendix 2 for other results). Even though the containers were plastic,several low-order ruptures were heard during the test, indicating that the internal pressure had risen before the fire burned through the plastic. The containers spilled their contents to form a 9.1m dia. poolfire .

The fire was not extinguished by sprinklers. It eventually ended when the flammable liquid was consumed. The test indicates that a larger array would have caused structural building damage.

Test No. 2

A second test was conducted with two pallet loads of the same paint thinner horizontally separated by 30mm. Each pallet load consisted of 216-3.8 litre containers in 36 cartons. Because of the results with the previous test,71 C rated,16.3mm orifice ("large drop") sprinklers were provided on 9.1sq.m. per head spacing. Discharge pressure was 5.2 bars. (Note: This protection is adequate for 3m high Level II aerosol storage under a 6m ceiling and for 1.5m high storage under a 9.1m ceiling.

The fire opened 42 sprinklers within the first 3 minutes. Eventually 45 sprinklers operated. The number of sprinklers opening within a short time period overtaxed the water supply, thus causing the discharge pressure to drop to 3.1 bars. Again, a large pool fire developed which was intense enough to burn 1/3 of the paint of both sides of a door located 10.3m from the array.

Alcohol Products (Concentrations near 100%)

Two tests were conducted with alcohol products. The first involved 0.25 litre plastic pump-type containers of hairspray consisting of ethyl alcohol,water, ester,isopropyl alcohol,aminonethyl propanol and fragrance. The flashpoint was 18 C and the mixture classified as a Class 1B flammable liquid. The second test used 3.8 litre polyethylene containers of essentially pure isopropyl alcohol. The flashpoint was 12 C and is classified as a Class 1A flammable liquid. The protection for both tests consisted of 12.7mm orifice, 138 C sprinklers on a 9.3m per head spacing. Sprinkler discharge was 2.0 bars.

The two pallet loads in the test with the smaller containers consisted of 192 cartons, each containing 12 bottles, for a total of 545 litres of product.

Each of the two pallets in the second test contained 216-3.8 litre polyethylene bottles in 36 cartons,about 820 litres of liquid per pallet.

Test No. 3

The fire developed slowly without the development of a large pool fire. By the time the two sprinklers operated,the first at 16 minutes 26 seconds and the second at 25 minutes 18 seconds,the pallets were saturated with released, burning liquid. Consequently,sprinkler discharge did not immediately extinguish the fire,but it did control the fire. The ceiling gas temperature over the ignition point reached a maximum of 182 C.

Test No. 4

Forty-one sprinklers opened during the test,but because the water supply was not overtaxed the 2.0 bars discharge pressure was maintained. Sprinklers did not control the fire. The ceiling air temperature over the ignition point reached 691 C and remained over 538 C for 1 minute 8 seconds.

Corn Oil

Test No. 5

A test using the same array and protection as the above alcohol tests was conducted with corn oil,a Class IIIB liquid (flash point about 254 C). During the test,oil leaked from the containers but had not ignited when the test was concluded after 30 minutes. The oil ignited when the building was ventilated, whereupon sprinklers opened and controlled the fire.

CONCLUSIONS

1. These tests show that container size for alcohol-type products affects fire severity. The larger containers spill more liquid into the fire than smaller ones, thus increasing the fire intensity at a faster rate.

   Other tests[7] have shown that the hazard of an alcohol-water mixture decreases as the alcohol concentration falls below 50%;at about 20%,it does not burn at all. There are two reasons for this. As the alcohol content decreases, so does the heat content of the resulting mixture. Secondly, sprinkler water dilutes a product containing 40% alcohol and 60% water faster than a product composed of 80% alcohol and 20% water. Thus,fire control of the former is quicker than that of the latter.

2. Both petroleum liquids and alcohol products (in concentrations near 100%) present a more severe hazard than aerosols, even though the plastic containers do not violently rupture or rocket. For instance, protection that is more than recommended for one pallet high Level III aerosols storage under a 9.1m high ceiling could not control one pallet high paint thinner which has a higher flash point than the toluene base used in the product for the aerosol tests.

   The protection provided for the essentially pure alcohol was adequate for one pallet high Level II aerosol storage,but, again, it could not control a fire with alcohol in 3.8 litre containers.

   The difference in size and strength between aerosol cans and plastic containers is one of the reasons for this difference. Plastic containers usually are larger than aerosol cans: A pallet load of plastic containers also can contain up to twice as much flammable liquid as a pallet load of aerosols. Thus,more product can be released from plastic containers when they melt through. For instance,the aerosol pallet loads used in Factory Mutual testing usually consisted of 1200-0.36 litre cans,which means each pallet load contained about 380 litres. The 3.8 litre plastic container tests,however,used up to 820 litres of liquid per pallet.

3. Testing[6] during the rack storage programme showed that protection adequate for a given ordinary commodity was overtaxed if a spilled 3.8 litres of flammable liquid was used as the ignition source instead of the standard ignitors. Thus,if flammable liquids in plastic containers are placed in the same cutoff areas as aerosols or flammable liquids in noncombustible containers, a fire starting in the plastic containers will create a spill fire that will involve the other products and may overtax the sprinkler protection. For these reasons, flammable liquids in plastic containers should be isolated from all other storages,including flammable liquids in glass,metal or aerosol containers.

4. Tests to date have only involved one or two pallet loads resting on the floor. Based on all other flammable liquid test data,a two dimensional spill fire is considerably less severe than the same size spill involved in a three dimensional fire such as could occur in rack storage. Because tests have not been conducted on rack storage,and a fire would be markedly more severe than a fire in palletized storage,it is not possible to provide guidance on how to protect such storage.

RECOMMENDATIONS

Location and Construction

1. Class I,II and IIIA liquids in small plastic containers (except those discussed in Section 5.3,Recommendation No.3)should be located in:

a. A detached building separated 15m from other important buildings,utilities fire pumps and other storage. If the building exceeds 23 sq.m.,sprinklers should be provided and designed in accordance with Protection ,Recommendation No. 1. If the building exceeds 46 sq.m.,it should be subdivided into 23 sq.m. sections by 2-hour rated,leak tight partitions. The building also may be subdivided into smaller areas to reduce the sprinkler demand.

b. A ground level cutoff room separated from the main building with 2-hour rated,liquid tight walls. Storage height should be limited to one pallet high. Ceiling height should not exceed 4.5m for effective sprinkler protection.

c. A trailer located 15m from important buildings or other storage.

d. A properly located,kerbed and drained outdoor storage area.

2. Drainage in cutoff rooms and detached buildings (see (a) + (b) above) should be designed to control the spilled flammable liquids and sprinkler discharge.

   There are several alternatives:

   a. If adequate drainage cannot be provided,design the room or building to contain the expected leakage and sprinkler discharge.

   b. Provide drainage to a separator tank sized for 125% of the room contents.

   c. Pipe the discharge to an impounding basin or lagoon located at least 30m from important buildings.

3. Products with less than nominal 50% water miscible flammable liquid content (and the remainder nonflammable),Class IIIB liquids,and water miscible liquids in plastic containers smaller than 0.5 litre may be stored in areas suitable for ordinary combustible commodities with respect to location,construction,drainage,control of ignition sources and ventilation except that Class I liquids should not be stored in basements.

Occupancy

1. Class I,II or IIIA liquids should not be stored in racks.

2. Class I,II and IIIA liquids should not be stored in the same area as flammable liquids in metal,glass or aerosol containers for the reason given in Conclusion No. 3.

Protection

1. Protect one-high palletized Class I,II and IIIA liquids with 71 C rated large drop diameter sprinklers on a 6.5 to 9.3 sq.m. maximum spacing. Base the water demand on 5.2 bars discharge pressure and the demand area on the size of the building or room. If the building is properly subdivided, base the demand area on the subdivision.

   Note: This protection will not necessarily extinguish a fire but it may protect the structure.

The demand area may be reduced by one-half if foam water or deluge sprinklers or foam monitors are provided. Other special extinguishing systems such as dry chemical or Halon may be used. If personnel are normally present in an area protected with dry chemical or carbon dioxide, provide a one minute delay (with alarm).

2. Treat products with less than nominal 20% miscible flammable liquid content (and the remainder non-flammable) as a FM Vlass III commodity (see Appendix 3) and those with nominal 20% to 50% miscible flammable liquids as FM Class IV (see Appendix 3) commodity.

3. Water miscible liquids in containers smaller than 0.5 litres and Class IIIB liquids in any size container should be protected in accordance with existing guidelines of Tables 4 and 5 FM Data Sheet 7-29.

REFERENCES

1. Factory Mutual Loss Prevention Data Sheet 7-29.

2. I. Chem E. Safety and Loss Prevention Bulletin.

3. Factory Mutual Loss Prevention Data Sheet 7-295.

4. Factory Mutual Record Magazine April 1982.

5. Factory Mutual Research Corporation Test Report No. OKOE3RR.

6. Factory Mutual Loss Prevention Data Sheet 8-33.

7. Factory Mutual Loss Prevention Data Sheet 8-8.

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APPENDIX 1

CLASSIFICATION OF FLAMMABLE LIQUIDS

Flammable and combustible liquids are classified by the U.S. National Fire Protection Association (NFPA) and Factory Mutual as follows:

Flammable Liquids defined as liquids having flash points below 38 C and vapour pressures not exceeding 2.76 bars at 38 C. Flammable liquids are referred to as Class 1 liquids and are subdivided as follows:

Class 1A Liquids - Those having flash points below 23 C and boiling points below 38 C.

Class 1B Liquids - Those having flash points below 23 C and boiling points at or above 38 C.

Class 1C Liquids - Those having flash points at or above 23 C and below 38 C.

Combustible Liquids defined as liquids having closed cup flash points at or above 38 C. Combustible liquids are referred to as either Class II or Class III liquids and are subdivided as follows:

Class II Liquids - Those having flash points above 38 C and below 60 C.

Class LLLA Liquids - Those having flash points at or above 60 C and below 93 C.

Class IIIB Liquids - Those having flashpoints above 93 C.

APPENDIX 2 FIRE TEST RESULTS SUMMARY

Test Commodity	Test No. 1 Paint Thinner	No. 2 Mineral Spirits	No. 3 Hairspray	No. 4 Isopropyl Alcohol	No. 5 Corn Oil
Arrangement	Single Pallet	1x2x1	1x2x1	1x2x1	1x2x1
Stack Height (m)	1.14	1.4	1.3	1.4	1.4
Clearance to Sprinklers (m)	7.8	7.6	7.5	7.6	7.6
Sprinkler Orifice Size (mm)	12.7	16.3	12.7	12.7	12.7
Sprinkler Temperature Rating (^{o}C)	138	71	138	138	138
Sprinkler Spacing (sq.m.)	9.3	9.3	9.3	9.3	9.3
Constant Water Pressure (bars)	2.0	5.2	2.0	2.0	2.0
First Sprinkler Operation, min:sec	4:31	1:53	16:26	2:57	After 30:00
Last Sprinkler Operation, min:sec	8:43	3:47	25:18	6:56	After 30:00
Total Sprinklers Opened	42	45	2	41	2
Total Sprinklers Discharge, (l/sec)	80	236	4	78	
Peak Gas Temp (^{o}C)	1246	621*	182	690	77
Peak Steel Temp (^{o}C)	660	99	138	246	63
Time Steel Temp Above 538^{o}C, mins:secs	3:30	0	0	0	0

* wetted thermocouple

APPENDIX 3

COMMODITY CLASSIFICATION

Stored commodities are classified into the following categories by Factory Mutual and the National Protection Association (NFPA).

Class - 1 - Essentially noncombustible products on wood pallets. They may be packaged in ordinary corrugated cartons or paper wrappings and contain a negligible amount of plastic trim such as knobs or handles.

Class - 11 - Noncombustible products in a wood crate or multiple thickness corrugated cartons or equivalent combustible material on wood pallets.

Class - 111 - Ordinary combustible materials (packaged or unpackaged wood, paper,natural fibre cloth) on wood pallets. Also,noncombustible products that contain a limited amount of plastic.

Class - IV - Class 1,11 or 111 products containing in themselves or their packaging no more than 25% by volume of expanded plastic or 15% by weight of unexpanded plastic,in ordinary corrugated cartons on wood pallets.