SAFETY INFORMATION PROFILE

HAZARDS OF FLAMMABLE AND COMBUSTIBLE LIQUIDS

STORED IN PLASTIC CONTAINERS

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The use of plastic containers for the storage of flammable and combustible liquids is profiled and the potential hazards are described. The general characteristics of polyethylene (9002884) containers are discussed, and the development of standards and specifications for plastic containers is outlined. Current Department of Transportation specifications and tests for polyethylene container are reviewed, and laboratory studies of mechanical properties leading to the failure of polyethylene are cited. The permeation properties of polyethylene are described. The authors conclude that the increasing use of plastic containers and the deficiencies in existing regulations indicate the need for further study in this area.

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PREFACE

JRB Associates developed this Safety Information Profile for the National Institute for Occupational Safety and Health under U.S. Department of Health and Human Services contract no. 210-80-0042. The profile reflects the literature available at the time that it was prepared, and is intended to provide an overview of the subject area. Safety Information Profiles are used by NIOSH to determine priorities and needs for future studies.

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EXECUTIVE SUMMARY

To the extent that statistical data are available, this safety information profile documents the incidence of use of plastic containers for the storage of flammable and combustible liquids and discusses the potential hazards associated with this use.

Because there are numerous types of plastics available for the manufacture of containers, a detailed description of all these materials would be extensive and beyond the scope of this profile. Therefore, efforts have been concentrated on polyethylene, which is the predominant material used in fabricating nonmetallic containers (1, 2).

Included in the profile are discussions of the following:

- General characteristics of polyethylene (1, 2, 3)
- Development of standards and specifications (1) for plastic containers
- Review of present Department of Transportation (1) specifications and tests and other tests for polyethylene containers
- Laboratory studies of mechanical properties (1) leading to the failure of polyethylene
- Permeation and reuse (4).

These are the most critical areas in the use of plastic containers for the storage of flammable and combustible liquids.

As a result of earlier discussions with the Division of Safety Research (DSR), 5- to 60-gallon containers have been emphasized, while the potential problems related to the use of plastic containers sized under 5 gallons have also been investigated. Statistical data pertaining to the incidence of using plastic containers for storing flammable and combustible liquids by corresponding Standard Industrial Classification (SIC) code were not available. However, data were available on the overall use of plastics for containers. Usage of high molecular weight polyethylene (HMWPE) in the fabrication of 30- to 55-gallon drums is rising at an annual rate of over 18%, from an estimated 12,000 metric tons used in 1976 to a predicted annual usage of 200,000 metric tons by the mid-1980's. This would comprise over 50% of the total drum market (1). The use of HMWPE shipping containers and utility pails took 30% of the market away from steel in 1975-76 (1). Additionally, HMWPE manufacturers produced 32% of the unit volume of 1- to 5-gallon containers (3).

From these data it appears that the use of plastics in the manufacture of containers is increasing and will continue to increase as long as economic factors favor this growth.

Within the Code of Federal Regulations, Title 49--Transportation, Parts 100 to 199, hazardous material regulations include specifications for plastic containers used in the transportation and storage of hazardous materials such as flammable and combustible liquids. These specifications require that containers be compatible with their respective lading and that plastic containers should not allow the lading to permeate to the extent that a hazard might result. However, there are no standards for deciding whether a plastic container selected for a particular use is or is not in compliance with the regulations. Similarly, there are no standards on reuse of plastic containers (1).

During fiscal year 1976, the Polymers Division of the National Bureau of Standards (NBS) conducted studies of the mechanical properties affecting plastic containers and of the properties of lading permeation through plastics under a Department of Transportation contract (No. A5-50074). These studies included a survey of the technical literature, an analysis of the tests presented in Title 49 CFR, a survey of other test methods, and laboratory studies on damage to polyethylene. The findings of these investigations were that performance criteria for permeation of lading materials should be developed and additional performance criteria should be implemented in the area of mechnical properties. These additional criteria should include the areas of failure due to stress cracking and to long-time, low-level applied stresses encountered in transporting and storing the container (1).

In recent years there have been a number of developments in the plastic container industry. Container fabricators have found ways to make sturdy, chemically resistant industrial containers in a variety of sizes and styles. Resin producers have developed materials that improve impact resistance, stress-crack resistance, and barrier performance of containers. Shippers have found that significant savings can be realized by using lighter plastic containers. The net result is that plastic containers are now competing in markets once considered to be exclusively for glass or metal containers (1, 2, 3, 4).

The lack of statistical data on the propagation of fires involving flammable and combustible liquids stored in plastic containers and on the population at risk, coupled with the increasing use of plastic containers and the deficiencies in existing regulations, indicate the need for further study in this area. An industrywide study is needed that would determine the incidence by SIC group of plastic containers used for storing flammable and combustible liquids, the population at risk, the precautions taken in selecting containers for various ladings, and the techniques now used to protect the containers and their ladings in the event of a fire. In addition, the criteria suggested by the NBS should be developed and implemented.

BACKGROUND ON PLASTIC CONTAINERS

Over the past 20 years, plastic containers used for storing liquids have increased in volume of sales as well as in the size of containers. The 55-gallon drums available today are products of the 1970's, evolved from the 1-gallon bottles of the 1950's and the 5- and 15-gallon pails and drums of the 1960's (5).

The use of plastic containers for storing and transporting flammable and combustible liquids has several inherent safety hazards. The Occupational Safety and Health Administration (OSHA) standard for such containers, 29 CFR 1910.106(d), limits the use of plastic containers. Only the 1-gallon size is permitted for combustible liquids and Class IC flammable liquids; the 1-quart size is allowed for Class IB and the 1-pint size for Class IA flammable liquids.

Plastic containers are usually not as strong as those made of glass or metal. Stacking must be limited to prevent the containers from collapsing, bursting, and causing a fire or explosion. Plastic containers are combustible and deform in the presence of heat. In the event of a fire, a plastic container cannot limit the spread of flames as much as glass or metal containers can. Plastic containers are frequently used to contain organic solvents. As a result, an additional consideration in their safe use is the possiblity that the solvent will attack the plastic and cause the container to weaken, crack, or split at the seams and leak the flammable or combustible contents.

These problems can be controlled by manufacturers and commercial dealers who are knowledgeable about the limitations of the containers. However, plastic containers are often used for handling and storing flammable and combustible liquids by workers who have little or no knowledge of the potential dangers. As long as plastic containers are used, this problem will be difficult to control, although aggressive safety education may be an effective means of reducing accident potential.

High molecular weight polyethylene is the most common plastic used in containers. Developed in 1957, HMWPE is classified as high density because it has a specific gravity of 0.940-0.965. In comparison to other plastics, HMWPE provides greater toughness, stiffness, and mechanical properties and is more resistant to stress cracking (3).

Polyethylene is obtained by the polymerization, or linking together, of many ethylene molecules. Polyethylene may vary according to the average size of the molecules or the molecular weight. The molecular weight affects the physical and chemical properties of the solid polymer and is therefore of critical importance during the manufacture of containers (1). Determination of molecular weight is usually expensive and is therefore not widely performed in industry. Instead, the melt index (a measure of the flow rate of the material) is determined. The melt index provides a comparative measure of the molecular weight. In general, the lower the melt index, the higher the molecular weight. The melt index is useful to polymer resin manufacturers as a method of controlling material uniformity and determining the mechanical properties of the final polymer (1). Table 1 presents some of these properties and their relationships to the melt index and molecular weight.

There are four types of polyethylene, and they are distinguished by their density. They are as follows (1):

- Type I--Polyethylene with a density range of 0.910–0.925 g/cm^3. This is termed low density polyethylene (LDPE).
- Type II--Polyethylene with a density range of 0.926–0.940 g/cm^3. This is termed medium density polyethylene (MDPE).
- Type III--Polyethylene with a density range of 0.941–0.959 g/cm^3. This is termed high density polyethylene (HDPE).
- Type IV--Polyethylene with a density of 0.960 g/cm^3 or greater. This is also termed high density polyethylene (HDPE).

Table 1. Relationship of mechanical properties of polyethylene to variations in melt index and molecular weight (6).

Property	As average molecular weight increases (melt index decreases)	As molecular weight distribution broadens
Melt viscosity	Increases	-
Tensile strength at rupture	Increases	No significant change
Elongation at rupture	Increases	No significant change
Resistance to creep	Increases	Increases
Impact strength	Increases	-
Resistance to low temperature brittleness	Increases	Increases
Environmental stress cracking resistance	Increases	Increases
Softening temperature	-	Increases

Of these, Type III is the type of polyethylene most frequently used in the manufacture of plastic containers (3). Table 2 presents the physical properties of these various resins.

Polyethylenes have excellent resistance to numerous chemicals and solvents. At ambient temperatures, they are resistant to acids and alkalies

Table 2. Physical properties of typical polyethylene resins (7).

Property	ASTM Test Method	ASTM Type I	ASTM Type II	ASTM Type III	ASTM Type IV
Density, g/cm^3	D 1505-68	0.910-0.940	0.926-0.940	0.941-0.959	0.960+
Environmental stress cracking, F_{30}, hrs.	D 1693-70	<1->1000	<1->1000	<1->1000	<1->1000
Tensile strength, 2 in/min, psi	D 638-68	1000-1900	1200-3500	3000-4000	3800-4700
Elongation, 2 in/min, %	D 638-68	>800	135-800	50-900	10-900
Modulus of elasticity, psi	D 638-68	8M-25M	25M-55M	60M-150M	110-150M
Modulus in flexture, psi	D 790-66	8M-60M	60M-115M	125M-210M	240M-260M
Vicat softening temp., °F	D 1525-65T	185-214	210-255	235-260	250-260
Brittleness, temp., °F	D 746-64T	<-180	<-180	<-180 to -35	<-180 + 70
Heat distortion temp., °F 66 psi	D 648-56	110-115	130-150	160-170	165-170
Coefficient of linear expansion, in/in/°C	D 696-70	1.0×10^{-4}	--	1.3×10^{-4}	1.3×10^{-4}
Thermal conductivity, Btu-in/ft^2	C 177-63	3.7	3.7	3.7	3.7
Specific heat, cal/gm	--	0.458	0.458	0.458	0.458
Taber index (mg lost/1,000 cycles)	Taber Abraser	10-15	6-10	2-5	2-5
Hardness, shore D	D 2240-68	44-48	45-60	55-66	65-70

with the exception of oxidizing agents such as nitric, chlorosulfuric, and fuming sulfuric acids. Polyethylenes are usually insoluble in organic solvents at temperatures below 50°C (123°F). However, at higher temperatures they are soluble to varying degrees in hydrocarbons and halogenated hydrocarbons. They are appreciably affected by chlorinated solvents, aliphatic and aromatic hydrocarbons, and certain esters and oils. Polyethylene can be dissolved at temperatures greater than 71°C (160°F) in toluene, xylene, amyl acetate, trichloroethylene, petroleum ether, paraffin, turpentine, and lubricating oils. In the presence of fire, these containers will release their ladings faster than a glass or metal container would, thus increasing the rate of propagation of the fire (1).

Polyethylene is permeable to gases, vapors, and liquids. The permeation rate depends on the physical state of the polymer as well as on the nature of the permeant. Material permeating the polymer may change the polymer's physical and mechanical properties (1, 2).

One possible consequence of permeation is a loss of lading from within the container. The hazard situation arises as a result of an accumulation of the lading in an area where it does not belong, such as a closed warehouse room. A second type of hazard can be created when a gas such as water vapor or oxygen penetrates a barrier and then reacts with the lading. The resulting chemical reaction may in itself present a hazard, or the reaction product may create a latent hazard. Another type of hazardous situation arises when a material remaining in the container walls from a previous use desorbs, and contaminates and reacts with the present lading. Even when there is no directly hazardous situation created by permeation the conditions may contribute to other failures. For example, if the lading of a container leaks faster than air enters, the resulting partial vacuum can collapse the container.

INDUSTRY DESCRIPTION

The use of plastic containers for storing flammable and combustible liquids is not limited to one major SIC group. Statistical data were unavailable during the development of this profile. However, the following SIC groups are known to use plastic containers for the storage of incidental flammable and combustible liquids:

- Major Group 27--Printing, Publishing, and Allied Industries
- Major Group 28--Chemical and Allied Products
- Major Group 55--Automotive Dealers and Gasoline Service Stations
- Major Group 75--Automotive Repairs, Services, and Garages
- Major Group 76--Miscellaneous Repair Services.

As discussed in the Executive Summary, an industrywide study is needed to ascertain the extent to which plastic containers are used for storing flammable and combustible liquids. Then the major SIC groups involved and the corresponding population at risk can be determined.

POTENTIAL HAZARDS

This section is divided into three parts and is a compendium of potential hazards associated with storing flammable and combustible liquids in plastic containers. The two parts are

(1) Catastrophic hazards--Those hazards that might result in one fatality, the hospitalization of five or more employees, or severe property losses.

(2) Hazardous dispensing operations--Those operations that might result in a fire or explosion leading to fatalities or serious injuries.

CATASTROPHIC HAZARDS

In the storage of flammable and combustible liquids in plastic containers, hazards that have catastrophic potential are

- Fire and explosion. Plastic containers will melt in the presence of fire and release their contents, which with flammable and combustible liquids will worsen the fire. The release of flammable and combustible vapors also increases the potential for serious explosions.

- Storage of flammable and combustible liquids that are not compatible with the plastic container. This may lead to heating of the containers, rupture, and possible fire or explosion.

- Storage of flammable and combustible liquids that may permeate the container. This increases the fire and explosion potential.

- Improper storage of containers, leading to stress cracking or other forms of mechanical failure. This may result in the release of the lading, and thus increase the fire or explosion potential.

HAZARDOUS DISPENSING OPERATIONS

During dispensing operations, spills of flammable liquids greatly increase the risk of fires. Unless containers are equipped with self-closing faucets, spills are likely to occur. To prevent this, plastic containers with self-closing faucets and flame arresters should be used.

ACCIDENT FACTORS

Occupational injury statistics on accidents involving plastic containers used for storing flammable and combustible liquids were not available during the development of this profile. Data sources contacted in an effort to obtain this information included the following:

- State of California Fire Marshal's Office
- State of Massachusetts Fire Marshal's Office
- National Fire Protection Association
- Society of the Plastics Industry.

These sources indicated that they had no data available relating to occupational injuries resulting from fires that were started or propagated as a result of storing flammable and combustible liquids in plastic containers.

EXISTING CODES AND REGULATIONS

A variety of Federal and State codes and regulations, as well as guidelines developed by trade associations, concensus standard groups, and manufacturers currently exist for the use of plastic containers for storing flammable and combustible liquids. Those that have been identified include

- Federal general safety standards as specified in 29 CFR 1910.106
- Federal safety standards for transporting hazardous materials as specified in 49 CFR, Parts 100-199
- American Society for Testing and Materials, ASTM D-1248-74, and ASTM D-3435-78
- National Fire Protection Association, NFPA 30, Flammable and Combustible Liquids Code
- Society of the Plastics Industry
  - Drip Input Resistance Test (PB1-4-1968) (Rev. 1978)
  - Polyolefin Bottle Permeability and Compatibility Test (PB1-5-1968) (Rev. 1978)
  - Top Load Stress Crack Resistance Test (PB1-11-1978)
  - Evaluating Flame Surface Treatment of PE and PP Bottles (PB1-6-1968) (Rev. 1978)
- Underwriters Laboratory
- Factory Mutual.

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