PACKAGING, CONTAINERS FOR INDUSTRIAL MATERIALS

1. Introduction

In any operation involving the manufacturing, distribution, and use of chemical substances, it is essential that consideration be given to packaging at an early stage of the manufacturing process. Container systems for industrial chemicals must fulfill several important functions: they must contain the product in order to be able to move it safely from point of manufacture to use; protect both the product from contamination and the immediate surroundings (plant, people, equipment) from the potential harm caused by the product itself; provide features that aid users in the effective utilization of the product; and communicate valuable information such as product identity, potential hazards, and handling information, to shippers and users.

The environmental impact of packages and packaging materials has come under increasingly vigorous scrutiny by all kinds of interests, ie, government and regulatory agencies, consumer groups, and environmentalists. It is becoming increasingly important that packaging for all kinds of products be developed in a rational manner, use less material, and have the ability to be recovered and reused whenever it is economically feasible and permitted by regulation.

Virtually any chemical can be stored and transported safely and effectively by using one of many package types. The choice of a container system, in general, is dictated by manufacturing, marketing, and economic considerations; for a chemical, however, the choice of packaging materials often is influenced primarily by safety and chemical compatibility factors. Both aspects can affect the cost of physical distribution, which often is comparable to the cost of the product being packaged.

2. Regulations

Regulations governing packaging and shipping of chemicals depend on the classification of the chemical as hazardous or nonhazardous. For nonhazardous chemicals, the packaging and shipping requirements are subject to the rules issued by the carrier. The most common of these rules are published in the *Uniform Freight Classification* for railroads and the *National Motor Freight Classification* for trucks. These rules are similar in that they both include sections listing the participating carriers, index to articles, article requirements, and packaging descriptions. The participating carriers have the right to collect a surcharge as well as to refuse handling or paying damage claims for articles not packaged according to the classification requirements (1,2).

There is also a procedure for trial shipments of new or improved packages. In such cases, the shipper must file an application for a test permit with the appropriate classification committee, supplying technical data to support the request. If the request is granted, a permit is issued. Test shipments must be marked as such, including reports filed on a timely basis during the test period. The shipper of the test package is responsible for all damage to the product, and must file reports with the commission that issued the permit. If, in the opinion of the commission, the package is good, a new package number will be issued.

Regulations controlling the packaging and shipping of hazardous materials in the United States are prepared by the Research and Special Programs Administration (RSPA) of the U.S. Department of Transportation (DOT). The primary document is Hazardous Materials Regulations (HMR) 49 CFR, parts 171–179. The *Code of Federal Regulations* (CFR) has been extensively changed to bring it into agreement with the international rules recommended by the United Nations Committee of Experts (3). As a result of these changes, materials packaged for shipment in the United States are acceptable worldwide; although in Europe there can be some differences based on the mode of transportation (qv).

In the words of RSPA, the changes to the regulations (*1*) simplify and reduce the volume of the HMR, (*2*) enhance safety through better classification and packaging, (*3*) promote flexibility and technological innovation in packaging, (*4*) reduce the need for exemptions from the HMR, and (*5*) facilitate international commerce (3).

The primary change in the HMR is in replacing the specific container requirements for products with performance orientated packaging (POP). In general, this means any package can be used as long as it passes certain rigid test requirements. The certification of a package is the responsibility of the shipper, who can self-certify the packaging or have the tests performed by an approved test laboratory. In the latter case, the test laboratory itself must be approved as a test facility by the DOT. The other change in the HMR is that shippers must provide the telephone number of either a company representative or a service that can be reached 24 h/d to answer questions regarding the nature of the hazardous material.

The CFR is divided into the following numbered sections: 171 for general information, regulations, and definitions; 172 for hazardous materials table, special provisions, hazardous materials communications requirements, and emergency response information requirements; 173 for general shipment and packaging requirements; 174 for carriage by rail; 175 for carriage by aircraft; 176 for carriage by vessel; 177 for carriage by public highway; 178 for packaging specifications; and 179 for tank cars specifications.

The HMR classifies hazardous materials into nine classes, some with subdivisions, as shown in Table 1.

Materials with the exception of explosives, gases, or radioactive classifications are also placed in packing groups. These groups define the relative danger of a material and, in turn, the package test requirements. Packing Group I denotes materials of great danger; II, of medium danger; and III, of minor danger.

The proper method for determining the packaging requirements for a hazardous material is to find the material listing in the Hazardous Materials Table of 49 CFR, section 172. From here the hazard class, identification number, packaging group, label requirements, special provisions, and packaging authorizations can all be ascertained. If any company has a tested package design for a similar type of product, that company may be allowed to use the design for the new product; otherwise, a new package must be designed and tested. Once the package has been approved, it must be marked with the U.N. package markings that specify the material, packing group for which the package has been approved, maximum gross weight or relative density of material for which the package was tested, whether the material is solid or under pressure, the year manufactured, the state or country of origin, and testing facility.

When ready for shipment, a package must have the identification number and proper shipping name marked in its upper left corner, the hazardous material labels centered in the panel, and the package marking in the lower left corner (Fig. 1). In addition, the shipping documents must show the hazardous material identification, hazard class, packing group, as well as a telephone number in case of emergency. Improper packaging, marking, documentation, or handling can result in civil and criminal liabilities against the shipper, package manufacturer, or carrier.

2.1. Transportation and Storage. Three considerations apply to both transportation (qv) and storage: compliance with legal requirements; package compatibility with the product as well as manufacturing and physical distribution requirements, such as safety requirements; and selection of an optimal-cost packaging system consistent with the preceding considerations. The interrelated nature of these factors, the variety of products to be shipped, the numerous packaging methods, and the large costs which are often associated with such decisions are all details that should be evaluated by a packaging specialist.

3. Bulk Handling of Products

3.1. Liquids. Approximately 170,000 railroad tank cars are used in the United States. The interior surfaces of these cars are tailored to carry a wide variety of products and are constructed of steel which is either unlined or lined with materials to enhance the chemical compatibility with a specific product; these lining materials include synthetic rubber, phenolic or modified epoxy resins, or corrosion-resistant materials such as aluminum, nickel-bearing steel, or stainless steel.

For commodities that solidify at temperatures commonly encountered during shipping, tank cars are equipped with internal or external heating coils. In some cases, cars are insulated with both sides of the insulation protected by thin steel shells. Approximately 15% of the tank cars in the United States are constructed for the transportation of pressurized commodities, such as anhydrous ammonia and propane.

If distribution requirements cannot be met by available tank cars, new car designs can be implemented; however, they are subject to the approvals of the Association of American Railroads and the DOT.

Tank cars have been constructed with capacities as great as 130,000 L ($\sim$34,000 gal) and weights as much as around 91 metric tons. The utilization of tank cars often represents an economical approach to the transportation of bulk commodities.

3.2. Solids. Increasing use of bulk cars, especially of covered hopper cars, has accompanied the expansion of the tank-car fleet. The principal drawback of bulk cars is the requirement for limited use, specialized cars, which necessitates a large investment. However, if such investment can be justified, the cost of transportation for dry bulk materials in hopper cars usually is less than those for goods in shipping containers. In many instances, such cars are used in closed-loop service; that is, they shuttle in unit trains between filling and discharge points. Similar equipment is also used in specialized highway vehicles whose truck bodies can incorporate dump hoppers and built-in conveyors.

Exotic materials are less likely to be used in the construction of hopper cars than in tank cars because of the lower chemical aggressiveness of solid chemicals compared to that of liquids and gases.

3.3. Semibulk Containers. Use of semibulk containers falls between bulk handling, eg, accomplished by tank cars and hopper cars, and individual package handling, which is often performed manually. Semibulk containers are also known as intermediate bulk containers (IBCs), the provisions and requirements for the construction and testing of which can be found in the U.N. recommendations (4).

Because volume capacity of a semibulk package can range from 400 L (110 gal) to 3000 L (790 gal), having a net weight of 225–2270 kg, cranes, lift trucks, and other powered materials-handling equipment are required for packaging and handling processes. Semibulk containers are either returnable or nonreturnable. Returnable models generally are made of metal and may be collapsible to minimize the cost of return shipment. Nonreturnable semibulk containers tend to be constructed of multiwall corrugated paperboard, typically with heavy gauge plastic liners, with pallets to facilitate moving and handling. The choice of either type of container is based on economics and industry practice, since functionally satisfactory versions can be produced for either type.

Note that Systéme Internationale (SI) units are employed in this article preceding English units. In U.S. trade practices and packaging specifications, however, English units are employed to the virtual exclusion of metric units.

4. Steel Drums and Pails

Drums are single-walled, cylindrical or bilged shipping containers with capacities of 49–416 L (12–110 gal). Although there are a small number of common-size steel drums, about 80% of all drums made have a capacity of 208 L (55 gal). Pails are containers having capacities of 45 L (12 gal) or less, usually characterized by cylindrical or truncated cone configurations, and often having a carrying handle (5).

When selecting a steel drum or pail of a given size, the most important factors to be considered are wall thickness and, if applicable, interior lining. Wall thicknesses, ie, general physical strength, usually are around 0.328–2.4 mm (28–12 U.S. standard gauge); linings are selected according to the product's chemical containment needs. Although drums can be reconditioned and reused under certain circumstances by specialized commercial operations, particular care must be taken in observing the associated regulatory and safety requirements. Steel drums are categorized as heavy, if the wall thicknesses are 1.09–2.40-mm thick (18–12 U.S. standard steel gauge), or light, if wall thicknesses are 0.328–0.960-mm (28–19 U.S. standard steel gauge). One common steel drum structure uses 20-gauge steel in the sides and 18-gauge steel for the ends (6). Although the use of steel drums in transportation of chemicals is in general wide-ranging and safe, their use for interstate transportation of hazardous materials is still subject to a set of minimum requirements.

Tight-head drums, ie, those having nonremovable ends, are usually equipped with two screw-type openings; typically the diameter of one is 19 mm (0.75 in.), and the other 51 mm (2 in.) (Fig. 2). The plug and gasket that comprise these closures may be metal or plastic. Other sizes of openings are also available; sometimes an opening can be located between the rolling hoops in the drum body.

The formulation and application of interior linings for steel drums have been the subject of intense development. Available in both clear and pigmented formulations, common varieties of linings are phenolic resin, polyethylene, or combinations of phenolic and epoxy resins. The lining formulation and thickness, which may be a function of its formulation, can be varied depending on the service needs (temperature range, handling abuse, corrosiveness, etc) of any particular lading. Most drum linings are applied by spray-painting.

Polyethylene-coated drums have been used for particularly aggressive products. Polyethylene (PE) coatings tend to be thicker than ordinary drum coatings; PE-coated drums have been used for storage and transportation of organic and inorganic acids, food products, paints, janitorial supplies, surfactants (qv), and agricultural chemicals. In certain instances, a PE-lined steel drum can be more economical than both glass carboys and stainless steel or aluminum drums. However, the chemical resistance of a PE-lined drum may not be as high, and storage life not as long, as those of drums that might be considered more permanent containers. Drums characterized by a virtually permanent life, and which can be used in severe environments, can be justified economically; such drums are generally fabricated from aluminum, Monel, stainless steel, or nickel.

U.N. packaging codes for metal drums are given in Table 2; thickness requirements for reusable drums are shown in Table 3.

5. Plastic Drums

Use of plastic drums is widespread in the chemical industry. These drums are used for packaging liquids, semisolids, powders, and granulated products. The shipper is responsible, though not solely, for verifying the suitability of containers, for checking DOT regulations and determining the suitability of plastic drums for a particular product, and for evaluating whether certain structural or material requirements are applicable. Two types of plastic drums are manufactured: free-standing plastic drums and plastic inserts for steel or fiber outer drums.

The principal advantage of plastic drums and liners is their resistance to corrosion. This aspect of their performance requires the lading to be investigated in terms of capacity for chemical attack on the drum. Stress-cracking tests should be performed in all instances where the compatibility of lading and drum material has not been established (6).

Plastic drums are made with either integral or removable heads, depending on the need of the customer. The chemical industry is more likely to use integral or tight-head drums, whereas the food industry is prone to use open-head drums to which separate covers can be fastened. The choice between these two styles often is determined by the requirement for cleaning the drum interior.

Capacities of plastic drums range from 9.5–208 L (2.5–55 gal) and the materials of construction generally are polyolefins. Small plastic containers are often placed and transported inside of corrugated boxes for convenience in handling. Large containers, especially the 208-L (55-gal) variety, are designed to be handled by a wide range of materials-handling equipments, including hand trucks, lift trucks, and cranes.

U.N. packaging codes for plastic drums are given in Table 2; thickness requirements for reusable plastic drums are shown in Table 3.

A composite drum is constructed of a plastic, semirigid inner liner (usually polyethylene) and either a steel or fiber outer container or overpack. The composite drum may be a useful compromise between a plastic drum and a conventional steel drum. It is strong enough to be handled like a steel drum, yet provides an enclosure for chemicals that cannot be shipped safely in steel or fiber drums. Capacities of composite drums are 19–208 L (5–55 gal). Such drums are used in chemical, pharmaceutical, and food industries.

6. Wooden Barrels

A barrel is a bilged, cylindrical container of greater length than width, having two flat ends (heads) of equal diameter. Because of their compound curves (the double-arch principle), wooden barrels can be extremely strong, capable of outperforming steel barrels in high stacking performance (6). A keg is a small barrel with a $\leq$38–L ($\leq$10–gal) capacity. In general, capacities of barrels are not uniformly defined and can vary depending on the product to be carried. For example, the capacity of a U.S. standard cranberry barrel is 95 L (25 gal), a U.S. standard fruit or vegetable barrel is 178–189 L (47–50 gal), a beer barrel is 117 L (31 gal), and a barrel of oil is 159 L (42 gal). Between one and two million wooden barrels were made in the United States in the mid-1990s; nearly all of these are 189-L (50-gal) charred-oak barrels were used for long-term storage and flavor development of whiskey.

Wooden barrels are made of staves that are bound with hoops, which are usually metallic. A slack barrel is not watertight, hence it is only suitable for powders, semisolids, and solids. A tight barrel is watertight and suitable for storage and shipment of liquids, but may also be used for semisolids and heavy solids. Like steel drums, wooden barrels can be reconditioned and recoopered. Except in rare instances, wooden barrels are not the preferred form of packaging for the storage and shipment of chemicals. U.N. packaging codes for wooden barrels are as follows: 2C1 for bung-type and 2C2 for removable head having a maximum capacity of 250 L (66 gal) and a maximum net mass of 400 kg (882 lb) (4).

7. Fiber Drums

A fiber drum is a cylindrical shipping container made of convolutely wound layers of fiberboard adhered to each other to form a solid wall. Construction materials for the ends include metal, plastic, and fiberboard. Fiber drums are subject to DOT and, for international shipment, U.N. regulations when used for hazardous materials. Reference to these regulations is necessary before selecting a fiber drum.

Although fiber drums are mostly used for the shipment of dry granular and semisolid materials, they are also used in conjunction with liners and coatings for liquid products. Usual capacities are 4–380 L (1–100 gal), but larger-volume drums are also available; inside diameters range from 20–58 cm and heights from 7.6–107 cm. The net weight packing limit for fiber drums generally is 250 kg, although higher weights can also be authorized for certain types of commodities and shipments.

In addition, because of the extreme variation in the bulk density of products, use of the standard 19-L (5-gal), 38-L (10-gal), 61-L (16-gal), 114-L (30-gal), and 208-L (55-gal) metal drums often results in excessive outage. Fiber drums, in contrast, are available in a wide range of sizes, and can be sized to meet product volumes, thus allowing for little outage as well as saving storage and shipping space.

The most common style is a fiber shell with a metal chime at the top and bottom of the drum. The chime connects the bottom securely to the side wall, thereby preventing leakage, infestation, and sifting. The top of the container is grooved so that a cover and locking band can be applied. There are several types of closures, including friction or telescoping slip-on covers (which are secured by gummed or pressure-sensitive tape), lever-locking rings and other types of bands, expanding or crimped lids, and metal lugs or clips.

Fiber drums can be produced to meet a wide variety of requirements. They can be constructed with adhesives for water resistance, their interiors can be coated, their walls and ends can incorporate metal foil or asphalt-impregnated plies, and their exteriors can be decorated by painting, varnishing, and silk screening for both ornamental and functional purposes.

A basic drum is often supplemented by blow-molded plastic inserts that fit closely into the interior cavity. These inserts generally are provided with molded fittings for filling and sealing. The combination, which is referred to as a composite drum, enhances the fiber drum for additional applications, especially for liquid and chemically aggressive contents that cannot be contained safely in ordinary fiber drums. The U.N. packaging code for fiber drums is 1G for a fiber drum having a maximum capacity of 450 L (119 gal) and a maximum net mass of 400 kg (882 lb) (4).

8. Bags

Bags of various constructions are used in the storage and transportation of dry chemicals. The choice of which type of bag to use should be based on the needs of the product for adequate protection and the requirements of the distribution network. To a certain degree, bags can be custom-made for a particular product; indeed, almost any shipping requirement can be satisfied by one of many combinations of paper, plastic, and natural fibers incorporated in the design of bags.

8.1. Textile. Textile bags are made from natural fibers such as cotton and burlap (see FIBERS, VEGETABLE). Burlap or Hessian cloth is woven from jute fibers. Because the supply of jute and, consequently, its price have been uncertain for many years, textile bags gradually have been replaced by various combinations of textile components with plastic or paper, multiwall paper bags, or plastic bags (see TEXTILES, SURVEY).

Burlap bags, which can be made in various weights according to product requirements, are exceptionally strong and highly resistant to tear and snag. They are available with special finishes, and may be printed for brand identification; they are used largely for agricultural crops and animal feeds. Collection and renovation services buy used bags for resale.

Cotton fabrics are used for domestic and export shipments of flour, processed grain products, animal feeds, and seeds. Although cotton bags possess various advantages such as attractive appearance and good resale value, their high price has caused them to decline significantly as a packaging medium.

Bag sizes are specified by the width of material used for fabrication; for instance, “102-cm, 0.3-kg burlap, cut 107 cm” denotes that a single bag is made from a web of 0.3-kg burlap which is cut 102-cm wide (40 in.) and 107-cm long (42 in.).

8.2. Laminated Textile. Laminated-textile bags combine strength and flexibility. They usually are made from burlap or cotton fabric bonded to one or more plies of various combinations of creped kraft paper, plastic film, and aluminum foil. Barrier material is selected to provide the appropriate degree and type of protection. Bags can be constructed with burlap or other fabric strength component either on the outside or buried as an intermediate ply in the wall of the bag. Combinations of materials result in laminated-textile shipping bags that are exceptionally strong and tear- and puncture-resistant. These bags can be stacked higher than conventional multiwall bags and be made to resist extreme weather conditions as well as moisture, odor, acid, and grease contamination; they can also package materials of high intrinsic value and replace rigid drums, thus saving storage and shipping space. Products commonly packaged in them include petrochemicals, drugs, insecticides, fertilizers, seeds, etc.

8.3. Multiwall Paper. Multiwall paper bags represent by far the most common type of bag used to store and transport chemicals. The terms sack and bag are often used interchangeably, although sack usually refers to heavier-duty bags. Several types of paper shipping sacks are used commonly in industry, featuring such constructions as sewn or pasted ends, gussets or flat, and a variety of valves (see PAPER).

Multiwall paper bags can be comprised of 2–6 tubular plies that are nested within each other. Generally, the material used in individual plies is heavy-duty kraft paper having a basis weight of 18–32 kg (39.69–70.56 lb) per ply. Basis weight is the weight, in pounds, of 3000 sq ft (279 m^2) of paper, based on a standard ream of 500 sheets measuring 24×36 in. ($\sim 60 \times 90$ cm). Inner plies may be either plastic-coated or plastic films. Individual plies may also be treated to provide wet strength, acid or alkali resistance, moisture barriers, and nonskid surfaces (7).

The versatility of the modern paper shipping sack is enormous. Thousands of products are packaged in multiwall paper bags, particularly agricultural products and supplies, but also chemical, food, and rock products. A few attributes that can be provided for paper shipping sacks are the inhibition of moisture migration in both directions, resistance to insect and rodent infestation, water repellency, containment of aromatic ingredients, protection against abrasion and scuffing, nonskid properties on outer surfaces for more stable storage and handling, U.S. FDA approval for packaging (qv), and a billboard appearance on the exterior for advertising purposes.

Protection capabilities of bags can be maximized by maintaining the moisture content of the paper at 6–8% by weight, relative to a shipping environment of 21°C at 60% in relative humidity. When the moisture content of shipping-sack paper drops below 6%, the sacks become excessively brittle; however, if short-term storage under such conditions is unavoidable, an attempt should be made to place them in an environment with adequate relative humidity for 24–48 hours prior to their use.

Multiwall shipping sacks are suitable for transport in all kinds of carriers from trucks to seafaring vessels. Particular care must be taken to prevent the storage of objects with sharp projections adjacent to the bags; in case of doubt, it is advisable to line the enclosure with kraft paper of a basis weight >23 kg. Additional rules for the transportation of multiwall sacks are contained in applicable tariff specifications and should be consulted for rail, truck, and ocean-going shipments.

8.4. Plastic. A plastic bag usually consists of a single heavy wall of plastic film, woven sheets of plastic tape, or laminates. Principal materials of construction are polyethylene and polypropylene (see FIBERS, OLEFIN). Both transparent and opaque sheeting are used, and printability usually is excellent. Plastic bags can be filled and closed with conventional equipment; heat-sealing is essential for open-mouthed bags to effect a moisture barrier.

Even though the use of woven plastic bags may be economically advantageous, their applications in the chemical industry are limited. For example, woven polyethylene bags made from film that has been slit into tapes is used for a number of agricultural and industrial applications. Such bags are more likely to compete with burlap bags than with the multiwall paper bag; in comparison with burlap, woven polyethylene bags are usually lighter in weight but equal in strength and superior in moisture and chemical resistance.

8.5. Filling. Almost all modern filling equipment is designed to insert a predetermined weight or volume of the product being shipped. Modern sack-filling equipment either delivers a predetermined weight of the product to the sack, or controls the weight that has been delivered by automatic shutoff after a predetermined level has been reached in the bag; weight accuracy is ca 0.25–1%. Most equipment used to fill open-mouthed bags operates on one of three principles: gravity feeding, auger feeding, or belt-conveyor feeding. Filling of valve-type sacks generally utilizes one of the following principles: centrifugal belt feeding, impeller feeding, auger feeding, or fluidized-bed feeding.

8.6. Closing. The closing of open-mouthed sacks can be accomplished by sewing, taping, wire tying, heat-sealing, or ultrasonic sealing. Where absolute tightness is required, thermal heat-sealing and, less frequently, ultrasonic sealing are preferred. Heat-sealing requires a heat-sealable coating on the inner ply. The closing of valve-type sacks is essentially automatic because of the construction of the valve.

U.N. packaging codes for bags are given in Table 4.

9. Flexible Intermediate Bulk Containers

A flexible intermediate bulk container (FIBC) is defined as an intermediate bulk container having a body made of flexible fabric. They cannot be handled manually when filled; are intended for shipment of solid material in powder, flake, or granular form; do not require further packaging; and is designed to be lifted from the top by means of integral, permanently attached devices (lift loops or straps).

Although usually made from woven polypropylene, FIBCs employ various fabrics depending on necessary container strength and factors of safety. The initial costs of these containers is high, therefore they are designed to be reused many times in a closed circuit system where problems of control logistics, prevention of contamination, cleaning and liability for loss or damage can be agreed upon by the shipper and receiver of the product. These bulk bags are used for dry, flowable products. Typical industries that use these FIBCs are food, chemical, refractories, and agriculture (8).

The flexible bulk container offers features that are unique to this package. It can be folded flat and bailed for shipment to the user. It offers a low weight:-product weight ratio. The cost is competitive and usually can be used without pallets. They are easy to store and handle in warehouses with standard equipment.

The DOT has included flexible containers with the other types of IBCs in Title 49 of the Code of Federal Regulations for Hazardous Products. When hazardous products are shipped, the UN mark must be printed on the container body. In the United States, the manufacturer of a third party laboratory can certify the container according to the regulations in part 178 of the Title 49 CFR. All other countries require a third party laboratory to certify the container.

10. Carboys and Bottles

Carboys are straight-sided, cylindrical bottles with characteristic capacities of 10–50 L (ca 3–13 gal) (5). They generally are made of glass, but they can also be made with earthenware, porcelain, or plastic. Carboys typically are enclosed in a protective outer container or frame to preserve glass carboys from damage and sometimes also to provide stacking and handling features for shipment. Carboys are identified as composite packaging in the U.N. recommendations; packaging codes for a variety of composite packagings are given in Table 4.

The traditional carboy is used primarily for shipping liquids that can be safely held only in glass containers, or products of extremely high purity. Such contents must be protected from all possible sources of contamination, including extraction of contaminants from the walls of the container. Glass carboys are heavy for the volume of product carried, and can weigh as much as 0.6 kg/L (5 lb/gal). Available in one-way and returnable varieties, carboys are in widespread use for the local shipment of spring water, distilled water, or drinking water; the typical outer protective frame can be of simple construction, from which the carboy is easily removed for product dispensation (5).

11. Boxes

When used in an industrial environment, the term boxes usually refers to rectangular containers made of corrugated or occasionally solid fiberboard. The general category of boxes may also include crates, which are rigid shipping containers typically made of natural wood or plywood, although they are rarely used in the transportation of chemicals. The term boxes as used here does not include folding cartons, which are unlikely to be used as packaging for storage and transportation purposes.

The designs and varieties of boxes that can be constructed and used in chemical packaging are many. This flexibility in design is possible because boxes are manufactured with minimal tooling expense under specifications that are unique to each order, but which are subject to various material specifications for meeting freight and shipping requirements.

The walls of corrugated boxes are comprised of at least two flat outer facings (liners) and a fluted (corrugated) interior component. Solid fiber containers are made from layers of paperboard, usually three or four plies in thickness and 1.5–3.6 mm in caliper. Dimensions and style of the box are controlled by the product's needs as well as the shipper's and receiver's materials-handling requirements. The basic style of shipping box is the regular slotted container (RSC); other styles include folders and telescoping constructions as well as constructions having interior flaps meeting at the centerline, overlapping, or with a gap (9). The U.N. packaging code for fiberboard boxes is 4G for fiberboard boxes made with a water-resistant outer liner and having a maximum net mass of 400 kg (882 lb) (4).

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Table 1. **HMR Classification**

Subdivision	Description
Class 1: explosives	
1.1	mass explosion hazard
1.2	projection hazard; no mass explosion hazard
1.3	fire hazard and minor projection or blast
1.4	no significant blast hazard
1.5	very insensitive mass explosion hazard
1.6	extremely insensitive detonating substances
Class 2: compressed gases	
2.1	flammable gas
2.2	nonflammable gas
2.3	poison gas
Class 3: flammable liquids	
Class 4: flammable solids	
4.1	flammable solid
4.2	spontaneously combustible
4.3	dangerous when wet
Class 5: oxidizing substances and organic peroxides	
5.1	oxidizer
5.2	organic peroxide
Class 6: poisonous and infectious substances	
6.1	poisonous substances
6.2	infectious substances
Class 7: radioactive materials	
Class 8: corrosives	
Class 9: miscellaneous dangerous substances	

Table 2. **U.N. Packaging Codes for Drums**[a]

Metal drums		Plastic drums	
Code	Description	Code	Description
1A1	steel nonremovable head	1H1	nonremovable head
1A2	steel removable head	1H2	removable head
1B1	aluminum nonremovable head		
1B2	aluminum removable head		

[a]Maximum capacity 450 L (119 gal) and maximum net mass 400 kg (882 lb); Ref. 4.

Table 3. **Thickness Requirements for Reusable Drums**

Volume, L	Metal drum thickness, mm[a]	Plastic drum thickness, mm[a]
20	0.60	1.2
40	0.70	1.8
120	0.90	2.2
220	0.96	2.2
450	1.80	5.0

[a]For approximate conversion to in., multiply by 0.04.

Table 4. **U.N. Packaging Codes for Bags and Composite Packagings**[a]

Bags[b]		Composite packagings[c]	
Code	Description	Code	Description
5H1	unlined or noncoated woven plastic bag	6PA1	within a steel drum
		6PA2	within a steel crate or box
5H2	sift-proof woven plastic bag		
		6PB1	within an aluminum drum
5H3	water-resistant woven plastic bag	6PB2	within an aluminum crate or box
5H4	plastic bag	6PC	within a wooden box
5L1	unlined or noncoated textile bag	6PD1	within a plywood drum
5L2	sift-proof textile bag	6PD2	within a wickerwork hamper
5L3	water-resistant textile bag	6PG1	within a fiber drum
5M1	multiwall bag of at least three plies, sift-proof	6PG2	within a fiberboard box
		6PH1	within an expanded plastic package
5M2	multiwall bag of at least three plies, having at least one waterproof ply, sift-proof		
		6PH2	within a solid plastic package

[a]Ref. 4.
[b]Maximum net mass 50 kg (110 lb).
[c]Composite packagings with inner glass, porcelain, or stoneware receptacles; maximum capacity 60 L (16 gal) and maximum net mass 75 kg (165 lb).

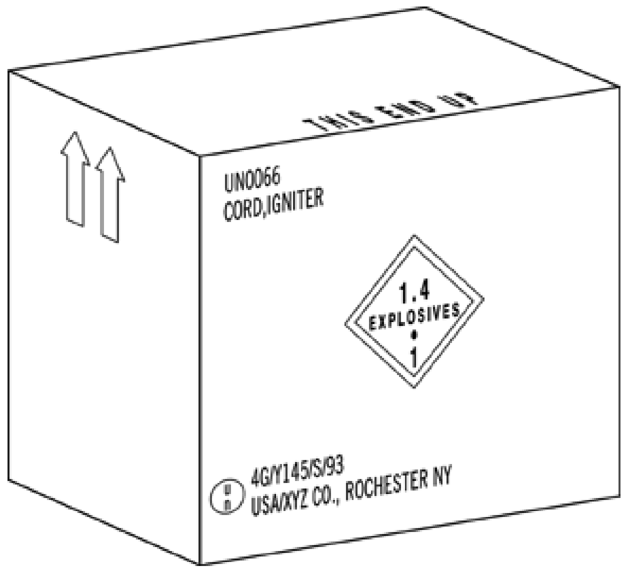

Fig. 1. Hazardous materials labeling and marking. The codes are as follows: (u n) is the United Nations packaging symbol; 4G, a fiberboard box; Y, the container may be used for materials in packing groups II and III, ie, products that pose a medium or minor danger; 145, the maximum gross mass in kilograms that may be packed into the container; S, the product is a solid; 93, the year in which the container was made; USA, the country authorizing the allocation of the markings; and XYZ, the name of the manufacturer of the container.

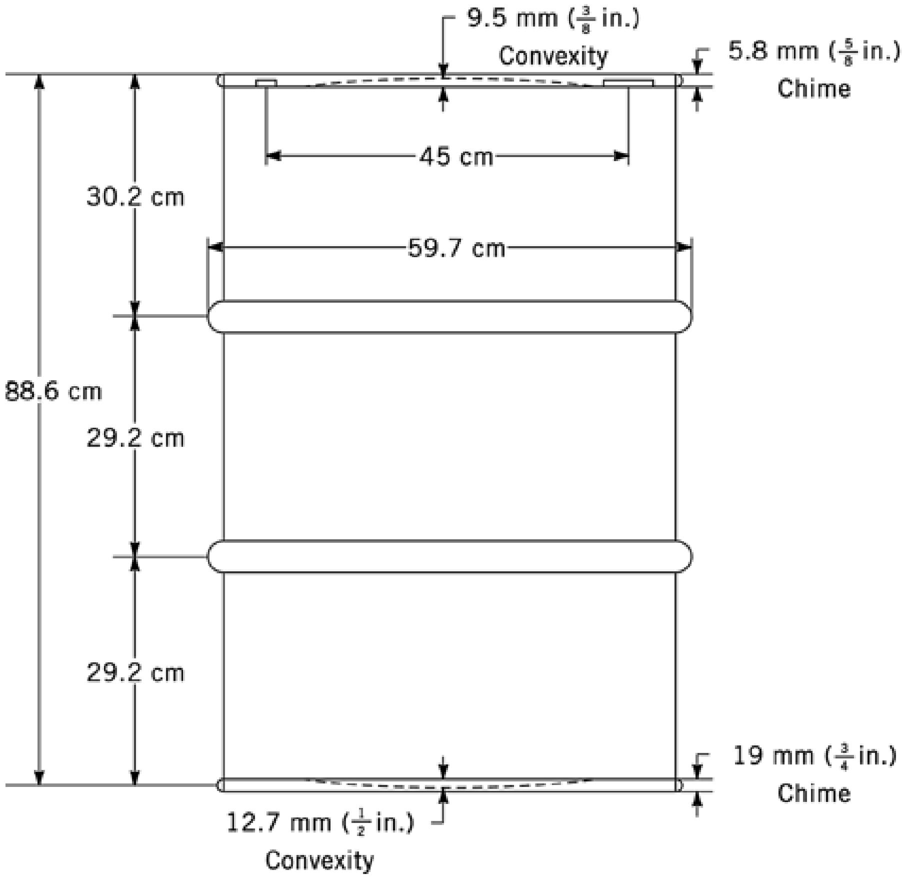

Fig. 2. Measurements of a tight-head drum; to convert cm to in., divide by 2.54.