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The Transportation of hazardous materials

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THE TRANSPORTATION OF HAZARDOUS MATERIALS

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ABSTRACT

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Effective January 1, 1991, both international and domestic hazardous materials must be transported according to the shipment required by the United Nation Recommendations (UN Recommendations). This mandate to follow the UN Recommendations has caused a lot of confusions for packers, shippers and shipping agents. Due to the confusion surrounding the use of this document, this thesis provides a basic guideline and complete instructions on how to handle hazardous materials smartly and safely.

Not understanding the regulations involved in hazardous material movement could result in much confusion in dealing with these type of materials. These analysis will clarify such areas as the responsibility of the shipper, shipping requirement, bills of lading regulations, terminology, and container constructions, which can help them in safe and effective handling of hazardous materials during transportation.

This thesis is divided into two sections: Section 1 deals with material classification, packaging marking, labeling, loading, paper work etc. Section 2 is the analysis of standard regulations of American Society for Testing Materials (ASTM) and US Department of Transportation (DOT) which developed a new test method, materials and construction specifications for packagings as well as miscellaneous information on hazardous material packaging.

OBJECTIVE

The objective of this thesis is to provide a basic guideline for hazardous material packaging for domestic and international transportation. Essential information from various sources and references is complied and presented in a simple and easy to follow manner. This will allow those unfamiliar with the current hazardous material packaging practice to quickly and easily understand the main requirements. Furthermore, those requiring even more detailed information on the various aspects of this form of specialized packaging may find the thesis useful in pointing out references which could provide them with the required information. In addition, some interesting aspects of the hazardous material packaging regulations are highlighted and discussed, thus reflecting the strengths and weaknesses of these regulations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION 1

1.0 INTRODUCTION

The hazardous materials regulations have evolved more than a century, beginning with a law to control the transportation of explosives by rail after the Civil War. The regulations have an inherent orientation towards particular modes of transportation that lasted under US Department of Transportation (DOT). Because of the advent of new materials, exigencies of modern transport systems, requirement to ensure the safety of people, property and environment, the United Nations Committee of Experts on the Transportation of Hazardous Materials are addressed to the concerned governments and international organizations. The purpose of the UN Recommendations is to allow domestic and international regulations governing various modes of transport to develop within a uniform fashion. Thus, contribute to worldwide harmonization in the transportation of hazardous materials.

With today's increasing trade both domestically and internationally, an increasing range and volume of hazardous materials are being handled, packaged and transported (Sheehan,1990). Confusion which leads to difficulty or delay in goods handling, as well as a high risk of exposing the materials to the environment could cause environmental damage or harm to humans. To reduce these risks, a number of regulations have been passed by various authorities and governments.

Due to this need, this thesis provides a basic methodology guideline for hazardous material packaging for domestic and international transportation to reduce confusion in hazardous material movement. Essential information from various sources and references are complied and presented in a simple and easy way to follow, which will allow those unfamiliar with the current hazardous material packaging practice to quickly and easily understand the main requirements. In addition, some interesting aspects of the hazardous material packaging regulations are highlighted and discussed, thus reflecting the strengths and weaknesses of these regulations.

Currently, domestic transportation within the United States: the Code of Federal Requirements (CFR 49) issued by the US Department of Transportation (DOT) Section 100-199 provides the regulations for hazardous material packaging. The regulations limit the quantity of hazardous material that can be handled in one package or shipment, as determined by the degree of toxicity, concentration, flammability, etc. Regulations also specify what type of primary container can come into contact with various contained substances, and specify materials which are to be used in the construction of the shipping container and required interior parts. They also indicate whether a color-coded label, any printed precautions or other markings are required, which place certain responsibilities on the carrier for proper handling and transportation.

For international transportation, hazardous material packaging regulations are provided in the Docket HM-181, performance oriented packaging standards, and the Standard Specification for Testing of Hazardous Materials Packaging (ASTM D-4919). The Docket HM-181 refers to the UN Recommendations (The Orange Book Chapter 9). DOT regulations are also applied to international transportation conditions at the destination country. Since the shipment will generally move by land carrier to a port of exit, all the UN Recommendations requirements are met in compliance with the full DOT regulation requirements.

This thesis is divided into 2 sections. In section 1, criteria for packaging design, testing, third party testing and standard instruction for hazardous material packaging which seeks to provide a high degree of environmental protection from the material being transported at a low cost are discussed.

For section 2, the performance oriented packaging standards (Docket HM-181) specifies procedures to test hazardous material packaging which is not specified by the UN Recommendations., The regulation also eliminates the complicated regulations of CFR 49. ASTM D-4919, the standard specification on the transport of dangerous goods, aims to improve the consistency of certification to the UN test requirements. This thesis also discusses the regulations of empty hazardous materials packaging, penalties, the statistic on accidents, the handling emergency responsibility and the computer data software.

2.0 HAZARDOUS MATERIALS PACKING INSTRUCTIONS

Before proceeding to discuss the basic requirements for hazardous material packaging, it is useful to clearly define some hazardous materials and packaging terminologies.

Hazardous materials are substances or materials that have been determined by the US Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce (Bierlein,1989). They include materials that are explosive, flammable, oxidizing, corrosive, pressurized, poisonous, radioactive and disease-producing. In addition, they include hazardous waste and hazardous substances as designated by the Environmental Protection Agency (EPA).

The UN Recommendations classified the packaging into 3 categories as follows:

(a) Inner packaging, which are the primary receptacles, and any other components necessary for the receptacle to perform its containment function, for which an outer packaging is required for transportation.

(b) Outer packaging, which provides an outer protection for the inner package, and which includes any absorbant materials, cushionings, or other components necessary to contain and protect inner packaging.

(c) Combination packaging, which combines inner and outer packaging for transportation purposes; for example, consisting of one or more inner packages secured in an outer packaging.

Based on CFR 49 and The UN Recommendations standard, in order to comply with domestic and international regulations, six steps must be followed when packing hazardous materials. The six steps are:

1. Classification
2. Determination of maximum quantities and types of packaging permitted
3. Selection of packaging
4. Filling and closing the packaging
5. Marking and labeling
6. Documentation

In this section the six steps are first described briefly before detailed explanations are provided.

2.1 Classification

The UN Recommendations, for sea, air, road, and rail transport regulations contain nine classes:

(a) Explosives (Class 1)

(b) Compressed gases etc. (Class 2)

(c) Flammable liquids (Class 3)

(d) Flammable solids; substances liable to spontaneous combustion; substances which, on contact with water, emit flammable gases (Class 4)

(f) Oxidizing substances; organic peroxides (Class 5)

(g) Poisonous (toxic) (Class 6.1), and infectious substances (Class 6.2)

(h) Radioactive (Class 7)

(i) Corrosives (Class 8)

(j) Miscellaneous dangerous substances (Class 9)

The classification and grouping depends upon the concentration of the substances. Some substances present more than one hazard. There is a table which enables such substances to be allocated to their correct class and division according to the primary hazard. In Classes 3, 6.1 and 8, there are detailed criteria. For instance, a liquid with a flash point below 60.5°C will be placed in Class 3 unless it has other hazards which take precedence over that of flammability.

2.2 Determination of Maximum Quantities and Types of Packaging Permitted

For most substances the modal regulations state the maximum quantity which may be transported in one package. The more dangerous the substance, the smaller the maximum per transport package. In the IMDG code (International Maritime Dangerous Goods) and RID (Regalements International Dangerous Goods)/ADR (European Agreement Concerning the International Carriage of Dangerous Goods by Road), regulations vary depending upon both the type of packaging and the substance contained within.

2.3 Selection of Packaging

The appropriate packaging must be selected from the types of packaging permitted. There are general packing provisions relating, for example, to the maximum degree of filling as well as to the compatibility between the substance and its packaging. For air transport, all packages containing liquids must be capable of withstanding a certain minimum internal pressure to allow for the effects of reduced atmospheric pressure due to higher altitudes.

2.4 Filling and Closing the Packaging

The selected packages are filled and closed in compliance with the appropriate regulations. The package should be effectively or securely closed for all modes of transportation.

2.5 Marking and Labeling

For sea and air transport, it is necessary to mark the package with the proper shipping name and often with other information, such as handling labels. All the labels designating hazardous materials are diamond-shaped. For RID/ADR transport, the labels required vary depending upon the packaging.

2.6 Documentation

The documentation and declaration required are specified either in general or in detail, and are transported with the package. For example, documents specifying stowage and segregation conditions are pertinent and communicate to the carrier and shippers, the type of ship or aircraft on which the packages are permitted (Mostyn,1986).

3.0 REGULATIONS ON HAZARDOUS MATERIAL TRANSPORTATION

For international transportation, the DOT regulations apply for transportation of hazardous materials as well for conditions at the destination country. Since the shipment will generally move by land carrier to a port area, all requirements of the International Maritime Dangerous Goods Code (IMDG), the International Air Transport Association (IATA), and the International Civil Aviation Organization (ICAO) codes are met as long as the full DOT requirements are met.

For domestic transportation, shipments imported into the United States must comply with DOT regulations. The importer must provide the foreign shipper with full information on how to prepare the shipment for transportation within the United States. The forwarding agent at the port of entry must be provided with full and complete information on hazardous materials by the DOT. The forwarding agent must also file with the initial domestic carrier a properly certified shipping paper as prescribed for transportation within the United States (Bierlein,1988).

There are four means used for the transport of dangerous goods: by sea, air, road, and rail. The United Nations Recommendations on the Transport of Dangerous Goods (the UN Recommendations) have world-wide relevance for all modes of transport. Both domestic and international standards are based on the UN Recommendations which offer guidelines for the safe transportation of all dangerous goods except radioactive materials. For transportation of dangerous goods by sea, the IMDG code is the domestic and international code of requirements to be applied to any goods that may pose a threat to the safety of the carriers or those on board. The IMDG is based on the UN Recommendations and is reviewed at intervals of approximately one year by the International Maritime Organization (IMO's) Sub-Committee on the Carriage of

Dangerous Goods. Packaged dangerous goods are normally transported in accordance with the IMDG code (Mostyn,1986).

Since January 1, 1984, ICAO has had world-wide applicability for international civil air transport and for domestic air transport. The ICAO Technical Instructions are based on the UN Recommendations and contain provisions under which competent authorities may authorize variations. For international air transport, dangerous goods have to be transported according tq the conditions for shipment required by the instructions of ICAO, which forms the basis for developing the regulations for the safe transportation of dangerous goods by air. The IATA contains all of the requirements of the ICAO plus additional requirements that are more restrictive than technical instructions reflecting standard industry practices or operational considerations (IATA,1990) as well as the UN Recommendations. Except for radioactive materials, the dangerous goods may be accepted in mail for air carriage subject to the provisions of the National Postal Authorities concerned. The shipper must comply with any necessary requirements for approval, notification, and inspection.

RID (Regalements International Dangerous) is enforced for international rail transport in some 33 European, North African, and Asiatic States. ADR (European Agreement Concerning the International Carriage of Dangerous Goods by Road) has legal force for international road transport in some 19 European states. RID and ADR normally contain identical or similar regulations (Mostyn,1986).

3.1 Classification of Hazardous Material

In general all the above regulations regarding hazardous materials are classified and defined according to risk, degree of danger, and characteristics. These classifications have been established to provide a common pattern in domestic and international regulations. In addition, these regulations specify the particular containers that are approved for the packaging of each material or type of material listed and give detailed structural specifications for each container. In simplified terms, compliance with the regulations requires the following steps, as follows:

(1) Determination of the hazardous properties of the material to be packaged.

In determining the container to be used for a new hazardous material, the properties of a hazardous material must be known. Shippers have to determine the hazardous classification of a given material by reference of the regulations. It should not be assumed; however, that the classification applying to a material for one set of regulations also applies to the other regulations.

(2) Determination of the hazard classification into which the material falls.

Classification of hazardous materials is usually made on the basis of material property test results. A hazardous material should be assigned to the classification corresponding to the results of the tests to which the material has been subjected.

(3) Identifying the containers approved for that type of hazardous material.

In identifying the containers to be used for a new hazardous material, verification of the classification should be undertaken in case that the hazardous material or its packaging is degraded in a way which might affect the behavior of the material.

(4) Proof of containers approved by the regulations (Fahy,1973).

After identifying the container for a new type of hazardous material, shippers have to approve the container by references of the regulations. Actually, these containers approved are satisfactory for the particular material under shippers consideration.

An analysis of material test report should be drawn up in accordance with the requirements of the competent authority.[1] It should contain the following information:

(a) The composition of the substance or the structure of the article

(b) The quantity of substance or number of articles per test

(c) The type and construction of packaging

(d) The test assembly, including in particular the nature, quantity, and arrangement of the means of initiation or ignition used

(e) The course of the test, including in particular the time elapsing until the occurrence of the first noteworthy reaction of the substance or articles, the duration and characteristics of the reaction, and estimate of the letters completeness

(f) The effect of the reaction on the immediate surroundings (up to 25 m from the site of the test)

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[1] From Chapter 9 of the UN Recommendations, the 9.7.1.5 states "The competent authority may permit the selective testing of packaging that differ in only minor respects from a tested type, e.g. smaller sizes of inner packaging or inner packaging of lower net mass; and packaging such as drums, bags and boxes which are produced with small reductions in external dimension(s)."

(g) The effect of the reaction on the more remote surroundings (more than 25 m from the site of the test)

(h) The atmospheric conditions during the test (The UN Recommendations,1990).

Water and air transport regulations, for instance, list the basic difference "solid" and "liquid". The measurement of viscosity is relatively straight forward when the substance exhibits Newtonian flow and a cup can be used. Viscous substances with an outflow time, via a DIN-CUP with a 4 mm diameter outlet at 20°C, exceeding 10 minutes should be considered as solid substances (Mostyn,1986).

RID/ADR regulations, however, define "solid" and "liquid" differently. For example, in classes 6.1 and 8, substances or mixtures of substances with a melting point above 45°C are considered to be Solids (Mostyn,1986).

There are nine classifications of hazardous materials according to type of risk, degree of danger, etc. The materials that fall within these classifications have been subjected to the UN Recommendations for hazardous materials transportation. The nine classes are as follows:

Class 1 - Explosives

Class 2 - Gases

Class 3 - Flammable liquids

Class 4 - Flammable solids

Class 5 - Oxidizing substances

Class 6 - Poisonous and infectious substances

Class 7 - Radioactive materials

Class 8 - Corrosives

Class 9 - Miscellaneous dangerous substances

In addition, special consideration must be given to substances with multiple hazardous classifications. Each of the classifications listed above will be described in the following section.

Class 1 Explosives

An explosive substance is a solid or liquid, which is in itself capable by chemical reaction of producing gas at such a temperature, pressure, and speed as to cause damage to surroundings, including a pyrotechnic substance which is designed to produce an effect by heat, light, sound, gas or smoke. These substances are evaluated for assignment to classification by testing their sensitivity to heat, impact, and shock wave, and by measuring the resulting violence of any reaction that may be triggered. Class 1 comprises:

(a) Explosive substances, except those which are too dangerous to transport or those where the predominant hazard is appropriate to another class.

(b) Explosive articles, except devices containing explosive substances in such quantity or of such a character that their inadvertent or accidental ignition or initiation during transport shall not cause any effect external to the device either by projection, fire, smoke, heat, or loud noise; and

(c) Substances and articles not mentioned under (a) and (b) which are manufactured with a view to producing a practical, explosive or pyrotechnic effect (The UN Recommendations, 1990).

These classifications are based on the UN Recommendations. Normally, explosive substances and ammunition are not permitted for air transport. The purity, stability, sensitivity (including sensitivity to vibration, temperature cycling, and pressure variation) and other physical properties of all explosives are considered for air transport (ICAO,1990). Class 1 is divided into five divisions:

Division 1 Substances and articles which have a mass explosion hazard.

Division 2 Substances and articles which have a projection hazard but not a mass explosion hazard.

Division 3 Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard.

Division 4 Substance and articles which present no significant hazard.

Division 5 Very insensitive substances which have a mass explosion hazard.

The classification of all new explosive articles and substances must be approved by the appropriate authority in the state of their manufacture. For the purpose of this provision, a "new explosive article or substance" is considered to be any of the following:

(a) A new explosive substance, or combination or mixture of explosive substances, which is significantly different from substances or mixtures previously approved.

(b) A new design of an explosive article, or an article containing a new explosive substance or new combination or mixture of explosive substances.

(c) A new design of package for an explosive article or substance including a new type of inner packaging (ICAO,1990).

Class 2 Gases : compressed, liquefied, dissolved under pressure or deeply refrigerated

There are two sets of criteria that are used for deciding whether substances should be in this class or not.

1. Simply, a substance is included if:
   - (a) It has a critical temperature of less than 50°C; or
   - (b) It exerts at 50°C a vapor pressure of more than 300 kPa (3 bar).
2. According to more complicated test procedures, a substance is included if:
   - (a) It exerts an absolute pressure of more than
     - (i) 280 kPa (2.8 bar) at 21.1°C; or
     - (ii) 730 kPa (7.3 bar) at 54.4°C; or
   - (b) It exerts a Reid vapor pressure of more than 280 kPa (2.8 bar) at 37.8°C (The UN Recommendations, 1990).

In practice, results obtained by applying either set of criteria vary slightly; the rigid application of one in preference to the other would not affect the classification of more than three or four of the substances listed in the Dangerous Goods List (The UN Recommendations, 1990).

This class comprises:

- (a) Permanent gases - gases which cannot be liquefied at ambient temperature.
- (b) Liquefied gases - gases which can become liquid under pressure at ambient temperatures.
- (c) Dissolved gases - gases dissolved under pressure in a solvent, which may be absorbed in a porous substance; and

(d) Deeply refrigerated permanent gases - e.g., liquid air, oxygen, etc. (ICAO,1990).

Class 2 also includes "aerosols," which means any non-refillable receptacle made of metal, glass, or plastic and containing a gas compressed, liquefied, or dissolved under pressure, with or without liquid, paste, or powder, and fitted with a self-closing release device allowing the contents to be ejected as solid or liquid particles in suspension in gas, as a foam, paste, or powder, or in a liquid or gaseous state (ICAO,1990).

Any compressed or liquefied gas except for an aerosol is defined as flammable if either a mixture of 13 percent or less (by volume), which when mixed with air, foams into a flammable mixture or the flammable range with air is wider than 12 percent regardless of the lower limit. These limits must be determined at normal atmospheric temperature and pressure (ICAO,1990).

An aerosol is regarded as flammable if it meets one of the two sets of criteria listed below:

(a) A test of aerosol produces any one of the following results:

1. With the valve fully open the discharged material is capable of being ignited by a flame applied for a period of 5 seconds at 150 mm from the valve orifice and the resulting flame length in a horizontal plane exceeds 450 mm, or with any degree of valve opening the flame flashes back and burns at the valve; or
2. With the valve fully open the discharged material, when directed into an open ended vessel containing an internal ignition source, causes a significant propagation of flame; or

3. With the valve fully open the discharged material, when directed into a closed vessel containing an internal ignition source, causes an explosion or rapid burning.

(b) The aerosol contains more than 45 percent by mass, or more than 250 g, of flammable components. Flammable components are gases which are flammable in air at normal pressures or substances and preparations in liquid form that have a flashpoint less than or equal to 100°C (ICAO,1990).

Class 3 Flammable liquids

Flammable liquids are liquids, mixtures of liquids, or liquids containing solids in solution or suspension which give off a flammable vapor at temperatures of not more than 60.5°C, closed-cup test, or not more than 65.6°C, open-cup test (The UN Recommendations,1990).

The packing group is based on the different hazards of the liquid. The packing group is determined from Table 1

Table 1 Packing Group Based on Flammability

Packing Group	Flash Point (closed-cup)	Initial Boiling Point
I (great danger)	-	≤35°C
II (medium danger)	<23°C	>35°C
III (minor danger)	≥23°C, ≤60.5°C	>35°C

Source: From the UN Recommendations,1990.

The hazard group of paints, varnishes, enamels, lacquers, adhesives, polishes, and other viscous flammable substances of Class 3 with a flash point of less than 23°C is determined by reference to:

(a) The viscosity expressed as the flow time in seconds.

(b) The closed-cup flash point.

(c) A solvent separation test; and

(d) The size of receptacle (The UN Recommendations,1990).

Viscous flammable liquids such as paints, enamels, varnishes, adhesives, and polishes with a flash point less than 23°C are placed in Group III provided that:

(a) Less than 3 percent of the clear solvent layer separates in the solvent separation test.

(b) The mixture contains not more than 5 percent of substances in Group I or Class 8, or not more than 5 percent of substances in Group I, Class 3 requiring a Class 8 subsidiary label.

(c) The viscosity and flash point are in accordance with the following table:

Table 2 The Viscosity and Flash Point of Flammability

Flow time in seconds		
4 mm cup	8 mm cup	Flash point in degrees Celsius
over 20	-	over 17
over 60	-	over 10
over 100	-	over 5
over 160	-	over -1
over 220	over 17	over -5
-	over 40	no lower limit

(d) The capacity of the receptacle used does not exceed 30 L (IATA,1990).

Class 4 Flammable solids: substances liable to spontaneous combustion; substances which, on contact with water, emit flammable gases

This class comprises:

Division 4.1 Flammable solids - Solids, other than those classed as explosives, which under conditions encountered in transport are readily combustible, or may cause or contribute to fire through friction.

Division 4.2 Substances liable to spontaneous combustion - Substances which are liable to spontaneous heating under normal conditions encountered in transport, or to heating up in contact with air, and being then liable to catch fire.

Division 4.3 Substances which, in contact with water, emit flammable gases - Substances which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities (The UN Recommendations,1990).

Self-reactive substances of Division 4.1 are liable to undergo at normal or elevated temperatures a strongly exothermal decomposition caused by excessively high transport temperatures or by contamination. In cases of ignition, they may react dangerously without the participation of air. Especially in cases of flameless decomposition, some substances may emit toxic vapors or gases. In addition, during the course of transport, packages or unit load devices containing self reactive substances of Division 4.1 must also be shaded from direct sunlight and stored away from all sources of heat in a well ventilated area (ICAO,1990).

Class 5 Oxidizing substances; organic peroxides

These are liquids or solids that yield oxygen readily when involved in a fire, thereby accelerating and intensifying the combustion of materials. There is no prescribed test for determining whether a substance is an oxidizer. The classification is founded upon advice from DOT or the Bureau of Explosives (Bierlein,1987). This class comprises:

Division 5.1 Oxidizing substances - substances which, while in themselves are not necessarily combustible, may generally, by yielding oxygen, cause, or contribute to, the combustion of other materials.

Division 5.2 Organic peroxides - Organic substances which contain the bivalent -0-0- structure and may be considered as derivatives of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals. Organic peroxides are thermally unstable substances, which may undergo exothermic self-accelerating decomposition. In addition, they may have one or more of the following properties:

- Be liable to explosive decomposition
- Burn rapidly
- Be sensitive to impact or friction
- React dangerously with other substances
- Cause damage to the eyes (The UN Recommendations,1990).

Organic peroxides are liable to exothermic decomposition which can be started by heat, contact with impurities, friction, or impact. The rate of decomposition increases with temperature and varies with the peroxide formulation. Decomposition may result in the evolution of harmful or flammable gases or vapors (ICAO,1990).

Class 6 Poisonous (toxic) and infectious substances

This class comprises:

Division 6.1 Poisonous (toxic) substances - these are substances liable either to cause death or serious injury or are harmful to health if swallowed or inhaled or by skin contact.

Division 6.2 Infectious substances: Substances containing viable micro-organisms or their toxins which are known, or suspected, to cause disease in animals or humans (ICAO,1990).

Class 7 Radioactive material

A radioactive material is a substance that spontaneously emits electrically charged atoms, called ions, that can cause damage to living organisms, (CFR 49 173.389). This can also be defined as any material for which the specific activity is greater than 70 kBq/kg. The specific activity means the activity per unit mass of a radionuclide or, for a material in which the radionuclide is essentially uniformly distributed, the activity per unit mass of the material (The UN Recommendations,1990).

The regulations regarding the transport of radioactive materials have been prepared by the International Atomic Agency (IAEA) in consolation with the United Nations, Specialized Agencies concerned and the IAEA's Member States.

Class 8 Corrosives

These are substances which, by chemical action, will cause severe damage when in contact with living tissue, or, in the case of leakage, will materially damage, or even destroy other goods or the means of transport; they may also cause other hazards (The UN Recommendations,1990). These substances are evaluated by specifically prescribed animal testing. Liquids are also considered corrosive if they rapidly corrode steel, as measured by spęcific tests.

Class 9 Miscellaneous dangerous substances

These are substances and articles which during transport present a danger not covered by other classes. These include magnetized material: Any material which has magnetic field strength of 0.159 A/m or more at a distance of 2.1 m from any point on the surface of the assembled package. Also regulated are any substances which have anesthetic, noxious, or other similar properties which could cause extreme irritation or discomfort to a flight crew member and prevent the correct performance of assigned duties (ICAO,1990).

3.1.1 Classification of Substances and Articles with Multiple Hazards

If a substance is not listed by name in the Dangerous Goods List and it meets the definitions for two hazards of those classes, it must be classified in accordance with the Precedence of Hazards Table (Table 3) this table indicates which of two hazards must be regarded as the primary hazard. The class which appears at the intersection of the two lines is the primary hazard; and the other class is a subsidiary risk. The packing group must be determined by reference to the criteria given for each of the classes concerned. The packing group is also shown at the intersection of the two lines in Table 3. If a substance has more than one hazard, one of which is of minor danger, it need not be considered in determining the classification of the substance. Except for pesticides, where a pesticide has the hazards of Class 3, Packing Group III, and Division 6.1, Packing Group III, the primary hazard must be Division 6.1 and Packing Group III (ICAO,1990).

Substances which meet, among other hazards, the criteria for any of Classes 1, 2, and 7 or Division 5.2 or 6.2, or which are wetted explosives, self-reactive substances of Division 4.1 or pyrophoric substances of Division 4.2, are not included in Table 3 since these classes, divisions and particular hazards always take precedence (ICAO, 1990).

A substance that is not specifically listed by the Dangerous Goods List is a liquid with the hazard of Division 5.1 or has three or more hazards. It is not covered by Table 3 and the advice of the appropriate authority of the state of origin must be sought.

Radioactive materials having other hazards must always be listed as Class 7, and the greatest of the additional hazards must also be classified, other than for excepted radioactive materials where the other hazardous properties take precedence. Infectious substances having other hazardous properties must always be classified in Division 6.2 and the greatest of the additional hazards must also be identified (ICAO,1990).

A sample of multiple hazards substance is the engine cleaner. This mixture of the cleaner will not be found in the hazardous materials table (CFR 49 Section 172.02). It is a liquid mixture of Gasoline and Carbon Tetrachloride with a flash point less than 23°C (see Table 1). The engine cleaner is classified as flammable liquid, Class 3 with Packing Group II, and a subsidiary risk, Class 6.1 with Packing Group II. The class which appears at the intersection of the two lines is the primary hazard, which is Class 3 with Packing Group II, and a subsidiary risk (See Table 3). So, the Packing Group for the engine cleaner is Class 3, Packing Group II which declares as Flammable liquid, poisonous, n.o.s[2] (Gasoline and Carbon Tetrachloride mixture).

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2 n.o.s. means not otherwise specified.

Table 3 - Precedence of hazards and packing groups for Classes 3, 4 and 8 and for Division 5.1 (Solids) and 6.1

Class or Division	Class or division and packing group									
and packing group	4.2 II	4.2 III	4.3 I	4.3 II	4.3 III	5.1 I (s)	5.1 II (s)	5.1 III (s)	6.1 I (i)	6.1 I (d)
3 I						--	--	--	6.1, I	3, I
3 II						--	--	--	6.1, I	3, I
3 III						--	--	--	6.1, I	6.1, I
4.1 II	4.2, II	4.2, II	4.3, I	4.3, II	4.3, II	4.1, I *	4.1, II	4.1, II	6.1, I	6.1, I
4.1 III	4.2, II	4.2, III	4.3, I	4.3, II	4.3, III	4.1, I	4.1, II	4.1, III	6.1, I	6.1, I
4.2 II			4.2, I	4.2, II	4.2, II	4.2, I	4.2, II	4.2, II	6.1, I	6.1, I
4.2 III			4.3, I	4.3, II	4.3, III	5.1, I	5.1, II	4.2, III	6.1, I	6.1, I
4.3 I						5.1, I	4.3, I	4.3, I	6.1, I	6.1, I
4.3 II						5.1, I	4.3, II	4.3, II	6.1, 1	6.1, I
4.3 III						5.1, I	5.1, II	4.3, III	6.1, I	6.1, I
5.1 I									6.1, I	6.1, I
5.1 II									6.1, I	6.1, I
5.1 III									6.1, I	6.1, I
6.1 I (i)										
6.1 I (d)										
6.1 I (o)										
6.1 II (i)										
6.1 II (d)										
6.1 II (o)										

(l) - liquid
(o) - oral
-- - an impossible combination
(d) - dermal
(s) - solid
(i) - inhalation

Table 3 - Precedence of hazards and packing groups for Classes 3, 4 and 8 and for Division 5.1 (Solids) and 6.1

Class or Division	Class or division and packing group								
and packing group	6.1 I (o)	6.1 II	6.1 III	8 I (l)	8 I (s)	8 II (l)	8 II (s)	8 III (l)	8 III (s)
3 I	3, I	3, I		3, I	--	3, I	--	3, I	--
3 II	3, I	3, II		8, I	--	3, II	--	3, II	--
3 III	6.1, I	6.1, II		8, I	--	8, II	--	3, III	--
4.1 II	6.1, I	4.1, II		--	4.1, I	--	4.1, II	--	4.1, II
4.1 III	6.1, I	6.1, II		--	8, I	--	8,II	--	4.1, III
4.2 II	4.2, I	4.2, II		--	8, I	--	4.2, II	--	4.2, II
4.2 III	6.1, I	6.1, II		--	8, I	--	8, II	--	4.2, III
4.3 I	4.3, I	4.3, I		4.3, I	4.3, I	4.3, I	4.3, I	4.3, I	4.3, I
4.3 II	4.3, I	4.3, II		8, I	8, I	4.3, II	4.3, II	4.3, II	4.3, II
4.3 III	6.1, I	6.1, II		8, I	8, I	8, II	8, II	4.3, III	4.3, III
5.1 I	5.1, I	5.1, I		5.1, I	5.1, I	5.1, I	5.1, I	5.1, I	5.1, I
5.1 II	5.1, I	5.1, II		8, I	8, I	5.1, II	5.1, II	5.1, II	5.1, II
5.1 III	6.1, I	6.1, II		8, I	8, I	8, II	8, II	5.1, III	5.1, III
6.1 I (i)				6.1, I	6.1, I	6.1, I	6.1, I	6.1, I	6.1, I
6.1 I (d)				8, I	6.1, I	6.1, I	6.1, I	6.1, I	6.1, I
6.1 I (o)				8, I	6.1, I	6.1, I	6.1, I	6.1, I	6.1, I
6.1 II (i)				8, I	6.1, I	6.1, II	6.1, II	6.1, II	6.1 , II
6.1 II (d)				8, I	6.1, I	8, II	6.1, II	6.1, II	6.1, II
6.1 II (o)				8, I	8, I	8, II	6.1, II	6.1, II	6.1, II

(l) - liquid
(o) - oral
-- - an impossible combination
(d) - dermal
(s) - solid
(i) - inhalation

3.1.2 Determination of Maximum Quantities and Types of Permitted

Once the hazardous material is correctly classified, appropriate packaging must be determined. In this part, aspects of packaging, including quantities, types, filling and closing are described. These general requirements apply to all classes except Class 2 and Class 7. These 2 Classes with specific activities are uniformly distributed. The regulations have been prepared by the International Atomic Energy (IAEA) in consolation with the United Nations, Specialized Agencies concerned and the IAEA's Member States (The UN Recommendations,1990). Hazardous materials must be packed in high quality receptacles in order to prevent leakage from the package which may occur, even in normal conditions, due to changes in temperature, humidity or pressure, or because of vibrations during shipment. These provisions apply to both new receptacles and reused receptacles. When a receptacle is reused, all measures must be redone to also prevent contamination (The UN Recommendations,1990).

Packaging in direct contact with hazardous materials must be resistant to any chemical or other reaction of the goods. The materials of the receptacles must not contain substances which may react dangerously with the contents, form hazardous products, or significantly weaken receptacles. Materials that can be significantly softened or rendered brittle or permeable by the temperatures during transport, or because of the chemical action of the contents or the use of the refrigerant, must not be used. It is the responsibility of the shipper to ensure that the packaging are compatible with the article or substances to be contained within such packaging (ICAO,1990).

The body and closure of any receptacle must be constructed so as to be able to resist the effects of temperature variations, pressure variations, and vibration occurring in normal conditions of transport. Stoppers, corks, or other friction-type closures must be held securely, tightly, and effectively. The closure device must be so designed that it is unlikely that it can be incorrectly or incompletely closed, and must be able to be checked easily to determine that it is completely closed (ICAO,1990). In addition, each packaging, except inner packaging in combination packaging (See 3.1.4), should conform to a design type tested in accordance with the UN Recommendations.

Unless specific requirements are prescribed in domestic or international rules, agreements, or regulations, liquid must not completely fill the receptacle at a temperature of 55°C. Sufficient outage must be left to ensure that neither leakage nor permanent distortion of the receptacle will occur as a result of a liquid expansion caused by temperature variations during the transport (The UN Recommendations,1990).

The closure which contains wetted or diluted substances should be the percentage of the liquid that does not fall below the prescribed limits during transport. Since pressure may develop in a package by the emission of gas from the contents, the packaging may be fitted with a vent which will not cause danger from its toxicity, its flammability, and the quantities released (The UN Recommendations,1990).

Hazardous materials must not be packed together in the same outer packaging with hazardous or other goods if they react dangerously with each other and cause the followings:

(a) Combustion and/or evolution of considerable heat

(b) Evolution of flammable, poisonous, or asphyxiant gases

(c) The formation of corrosive substances

(d) The formation of unstable substances (ICAO,1990).

Subject to the above, an outer packaging may contain more than one item of hazardous materials provided that :

(a) The inner packaging used for each item of hazardous materials and the quantity contained complies with the relevant part of the packing instruction applicable to that item.

(b) The outer packaging used are permitted by all the packing instructions applicable to each item of hazardous materials.

(c) The package as prepared for shipment meets the specification performance tests for the most restrictive Packing Group of a substance or article contained in the package.

(d) The quantities of different hazardous materials continued in one outer packaging must be such that "Q", which does nor exceed the value of 1, where "Q" is calculated by using the formula:

$$Q = \frac{n1}{M1} + \frac{n2}{M2} + \frac{n3}{M3} \ldots$$

where n1, n2, n3, etc are net quantities of the different hazardous materials and M1, M2, M3, etc are maximum net quantities for these different hazardous materials; and

(e) The hazardous materials do not require segregation, unless otherwise provided in these instructions.

An outer packaging of hazardous goods must not contain inner packaging of Division 6.2 (Infectious substances) and inner packaging of other types of goods (ICAO,1990).

Inner packaging must be packed, secured or cushioned so as to prevent breakage or leakage and to control movement within the outer packaging during normal conditions of transport. The cushioning material must not react dangerously with the contents of inner packaging. Any contents leakage must not substantially impair the protective properties of the cushioning material.

In the packaging instructions, liquids in Classes 3, 4, 5, 6 or 8 of the Packing Groups I or II, in glass or earthware inner packaging must be packaged by using materials capable of absorbing the liquid. The absorbent material is required when an outer packaging is not liquid tight. Where absorbent material is required, its quality and disposition in each outer packaging must be as follows:

(a) For packaging containing liquids in Packing Group I for transport on passenger aircraft; sufficient absorbent material to absorb the contents of all inner packaging containing such liquids.

(b) For packaging containing liquids in Packing Group I for transportation cargo aircraft: sufficient absorbent material to absorb the contents of any one of the inner packaging containing such liquids and, where they are of different sizes and quantities, sufficient absorbent material to absorb the contents of the inner packaging containing the greatest quantity of such liquid. For packaging containing liquid in Packing Group II for transport on cargo aircraft only, no absorbent material is required (ICAO,1990).

The nature and thickness of the outer packaging must not generate any heat likely to dangerously alter the chemical stability of the contents during transport. Where pressure may develop in a package by the emission of gas from the contents, the packaging may be fitted with a vent provided that the gas emitted will not cause danger on account of its toxicity, its flammability, the quantity released etc. The vent should be so designed that leakages of liquid and the penetration of foreign substances are prevented under normal conditions of transport. Venting of the package should not be permitted for air transport, except as otherwise specified in the instructions (The UN Recommendations, 1990).

Combination packaging containing liquid hazardous materials, excluding flammable liquids in inner packaging of 120 ml or less, must be packed so that the closures on the inner packages are upward and the upright position of the package must be indicated on it by the "package orientation" label. The words "This side up" or "This end up" may also be displayed on the top of the package, except for a package where there is inadequate space to affix all necessary labels and markings.

New, reused or reconditioned packaging should be capable of passing the tests. Before being filled and handed over for transport, every packaging should be inspected to ensure that it is free from corrosion, contamination or other damage. Any packaging which shows signs of reduced strength as compared with the approved design type should no longer be used or should be reconditioned so that it is able to withstand the design-type tests.

An empty packaging that has contained a hazardous material should be treated in the same manner as is required by the recommendations for a filled packaging until it has been purged of the residue of the dangerous substance (ICAO,1990).

3.1.3 Exemptions and Relaxations for Small Quantities

The UN Recommendations contain provisions stating that very small quantities of packaged dangerous goods which pose a small danger can either be exempt from the regulations or qualify for relaxations.

The IMDG Code contains provisions for :

(a) Exemptions related to the substance, and the quantity per inner packaging, per package, and per consignment.

(b) Relaxations subject to competent authority approval.

(c) The general scheme for limited quantities, related to the substance and the quantity per inner packaging, per package and per consignment (Mostyn,1986).

The IMDG Code includes three forms of limited quantity provisions for most substances of Classes 2, 3, 4, 5, 6, 8 and 9:

(a) Exemptions--total exemption from the provisions of the IMDG Code for very small quantities.

(b) Packing relaxations--relaxations, subject to competent authority approval, for dangerous goods in small receptacles.

(c) Fiberboard boxes, fiber or metal drums. Packaging should comply with Packing Group III performance tests. Packages should be marked as "dangerous" (Mostyn,1986).

For air transport, the regulations do not contain provisions for limited quantity exemptions or relaxations. Dangerous goods should not be permitted in the mail except for infectious substances and specified radioactive materials which are subject to the provisions of the national postal authorities concerned and to the provisions of the instructions. However, Packing Instruction 910 covers cosmetics, drugs and medicines which are packed for retail sale or distribution for personal or household consumption. The package must comply with the requirements of the Packing Instruction and is not subject to the requirements of the regulations except in relation to documentation (Mostyn,1986).

Dangerous goods which must not be carried on aircraft under any circumstance are :

(a) Various categories of explosives, flammable solids, organic peroxides and pyrophoric radioactive liquids.

(b) Any substance which is liable to produce a dangerous evacuation of heat or gas under the conditions normally encountered in air transport (Mostyn,1986).

The RID/ADR regulations contain exemptions. Most Class 3 inflammable liquids of Packing Group III for example are not subject to the provisions of RID/ADR when in quantities not exceeding 3 liters per inner packaging and 45 liters per package irrespective of the quantity per consignment (Mostyn,1986).

3.1.4 Exemptions and Relaxations for Design Changes in Combination Packaging.

The requirements to comply with the UN testing and certification standards have serious implications for combination packaging. Therefore, it is necessary to understand the definitions for combination packaging and packaging design type, because of its use in the UN Recommendations:

Combination packaging consists of one or more inner packages secured in an outer pack.

Packaging design type is defined by the design, size, material, and thickness, manner of construction, and packaging. However, it may include various surface treatments and packaging which the height differs from the design type (Altemos,1990).

The primary goal of a package is to prevent leakage or breakage of the inner receptacle(s). Thus, the integrity and fragility of the inner packaging must be closely controlled. The interplay of the inner receptacles with each other and with the cushioning and bracing are as important as the individual fragilities of each receptacle. Performance of a complete package is not achieved simply by choosing good package components; their interactions during laboratory and field dynamics define package performance (Sheehan,1990).

Depending on the mode of transit, regulations include some special provisions for combination packages to ship limited quantities of hazardous materials. The full certification requirement may be relaxed, but package performance is still specified. This may, reduce some of the testing burden on shippers.

Recent regulatory activity allows some substitution of inner packaging to be different from those tested and certified. The regulations provide limitations of size, fragility, cushioning, etc. for inner packaging. They will allow shipment of combination packages which have not been fully tested in accordance with the UN Recommendations. However, they do not change the requirements of being fully capable of passing the UN Recommendations standard tests (Anon,1990).

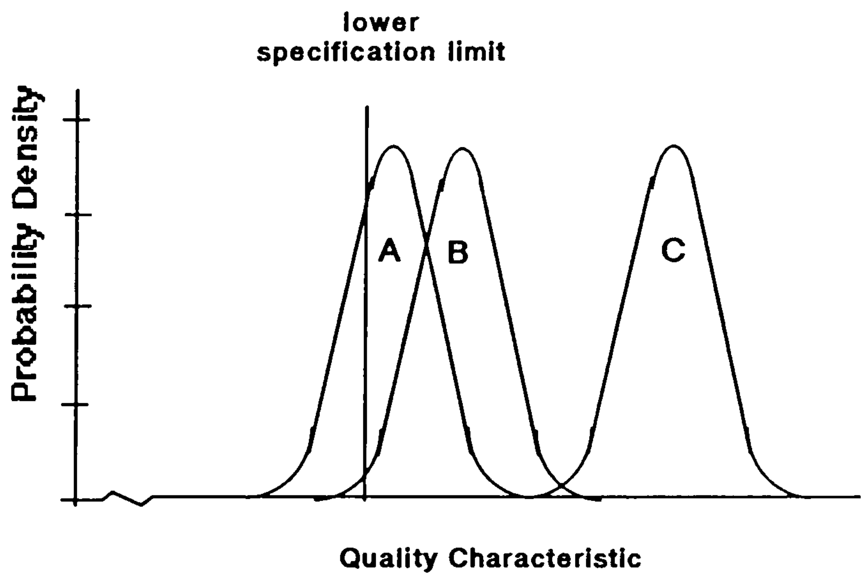
Another relief from full testing of all combination packaging allows untested inner packaging with "over-designed" cushioning and outer packaging. Absorbent material, a leakproof bag or liner, and other strict requirements are also delineated for this special package.

3.1.5 Components of Combination Packaging

The performance of combination packaging is specified by the UN based testing, most individual components will continue to be manufactured by material characteristics and purchased by a manufacturer's product identification or specification. The challenge is to specify, purchase, and assemble all components so that the aggregate performance of production packaging remain above UN specification levels.

All package components have some variation in dimension and physical properties. Using statistical analysis a minimum specification limit for these quality characteristics can be determined. These minimum limits are useful to ensure that a final package would meet the required specification. For example, figure 1 shows the distribution of an important physical property of three similar package components. When performance testing was conducted, the lower specification limit showed that product B meets the requirement of the given statistical limit, while product A could be faced with shipment rejection due to combination package performance falling below the UN specified limit. On the other hand product C is likely to fully satisfy the UN performance level. In this example product C is better than A or B and it could be argued that package re-testing would not be necessary with product C (Sheehan,1990).

Figure 1 The Quality Characteristic of Components or Materials



Source: From The Chemical Packaging Review, volume IX, number 1, p.17 "Implementing the United Nations Performance Standards for Packaging" by Richard Sheehan, 1990.

Technically, almost any change in components or of supplier would require re-testing and recertification of the combination package. Practically, some change in multi-component packaging is a regular occurrence in a production operation.

If relatively minor variations made to successful test packaging were deemed to constitute a new design type, requiring complete retesting and certification, the amount of testing that would have to be performed would be excessive. The UN recognized that the selective testing provisions of paragraph 9.7.1.5[3] of the UN Recommendations could provide considerable relief from the need to test many variations. However, this paragraph provided no specific guidance on what types of variations were allowed to be made to a packaging without requiring that packaging to be retested and certified as a new design type.

The meeting of the UN Committee of Experts on the Transport of Dangerous Goods (1990) considered reducing the amount of testing required in connection with the implementation of the UN Recommendations for combination packaging. It was decided that these problems could be overcome by clarifying the existing selective testing provision to indicate more precisely the nature of variations that may be made to a tested combination packaging without requiring the modified packaging to be retested.

The basic philosophy was a "worst case" combination packaging were tested successfully, if similar packaging less susceptible to damage in transport and handling could be permitted without retesting. A packaging "less susceptible" to damage would generally be one where smaller and/or less fragile inner packaging, as compared to the

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[3] From Chapter 9 of the UN Recommendations, the 9.7.1.5 states "The competent authority may permit the selective testing of packaging that differ in only minor respects from a tested type, e.g. smaller sizes of inner packaging or inner packaging of lower net mass; and packaging such as drums, bags and boxes which are produced with small reductions in external dimension(s)."

inner packaging used in the previously tested packaging, are placed in the same outer packaging used in the original test. When smaller inner packaging are used, the resulting additional void space would have to be filled with cushioning material to ensure that the variant packaging would still be capable of successfully passing the performance tests if it were subjected to them.

To allow immediate application of these selective testing provisions, the DOT was defined as the "competent authority" of the United States for purposes of the application of these international standards, published in the Federal Register on March 22, 1990 (55FR 10750) in a "competent authority ruling" that reflects the January UN decisions. As a result, persons within DOT jurisdiction may now apply these selective testing provisions to the testing and certification of combination packaging following UN Chapter 9 (Altemos,1990).

Examples of a combination packaging include glass or plastic bottles, metal or aerosol cans contained in a fibreboard or wooden box or other suitable outer packaging. Under the UN Recommendations, combination packaging must be tested and qualified as a complete unit with inner packaging, cushioning material and any other packaging components in place. The configuration of this complete packaging is defined as the design type according to UN Chapter 9.

It is important to remember that before one can apply the criteria for selective testing to a particular packaging, it is necessary to have a combination packaging that has been fully tested and certified. In addition, the outer packaging must always be of the same material, strength, manner of construction, closure, and identical to the outer packaging used for the reference packaging originally tested and qualified. Holding this outer packaging constant, variations to the number and type of inner packaging that can be made without retesting are subject to the conditions and limitations contained in the DOT competent authority ruling (Sheehan,1990).

Nevertheless, the selective testing guidelines as applied to a fully tested, and certified UN combination packaging still depends on the individual needs of packagers. There might be advantages to selecting and testing more than one "reference"[4] packaging. This is due to the condition of the selective testing ruling which provides that when a lesser number of inner packaging are used as compared to the tested reference packaging, sufficient cushioning material must be added to prevent significant movement of the inner packaging. While the ruling would allow use of only one 1-litre bottle in an outer packaging that had been tested with four 1-litre bottles, the amount of cushioning required to fill the resultant void spaces could make this a less than desirable solution from the practical point of view.

Under UN Recommendations, testing and certification of this packaging may have been accomplished either through a process of self-certification or through the use of a DOT recognized third party laboratory. The choice of either of these two processes in certification of the reference packaging has no bearing on the application of the selective testing provisions. However, certification according to one or the other of these procedures must be accomplished before the selective testing guidelines can be applied. Therefore, in order to assure compliance of packaging with the selective testing provisions, it is first necessary to have documentation supporting the initial testing, certification, and marking of the reference packaging in accordance with the applicable UN Recommendations.

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[4] "reference" means testing and certification of the package.

As with any records used to support certification of packaging to U N Recommendations, the records concerning the reference combination packaging should describe in detail the packaging tested and certified. The following information should be included: the type and general description of the packaging, construction materials, dimensions, thickness, minimum burst strengths for fiberboard, methods of closure, complete description of inner packaging, number and arrangement of inner packaging, type, quantity, and arrangement of cushioning materials and any other information to describe thoroughly the packaging design type originally tested.

In general, the person responsible for compliance with the applicable UN Recommendations is the one identified in the UN marking as "the name of the manufacturer or other identification of the packaging specified by the competent authority." Under procedures established by DOT for marking and certifying UN packaging, the general format of this part of the marking will vary according to whether the packaging was certified through third-party testing or through self-certification. In any event, the markings appearing on the reference packaging clearly identify it as a specific, tested design type. When applying the selective testing provisions, the markings appearing on the variant combination packaging should be identical to those appearing on the reference packaging. The person identified in those markings remains responsible for establishing compliance of the reference packaging under applicable UN Recommendations (LeBlance,1990).

Anyone who creates a variant to a reference packaging, within the constraints of the selective testing provisions, will be responsible for demonstrating compliance with those provisions even though he or she may not be specifically identified through the packaging markings. Written documents should be maintained providing the rationale behind a variant. The manufacturer of a variant packaging should also keep testing documentation that proves a variant packaging conforms fully to the selective testing guidelines. Such documentation will be essential in the event of a DOT enforcement action or liability issue associated with conformance of the packaging to the applicable standards.

The selective testing provisions allow changes only to the number and type of inner packaging. The outer packaging which, under the UN Chapter 9 definitions, also includes absorbent materials, cushioning materials, and any other components necessary to contain and protect the inner packaging, must always remain exactly as in the reference packaging. However, most of the variations allowed by the selective testing provisions are straight- forward, and documenting conformance with these guidelines in order to establish the acceptability of variant designs is not difficult. For example, reducing the number of inner packaging and filling the resultant void with cushioning material would not require extensive documentation to substantiate compliance with the selective testing provisions (Altemos,1990).

Documentation of the acceptability of some of the variations may be more challenging. For example, when substituting inner packaging of a different construction material, it is necessary to establish that the resistance to impact and stacking forces of the new inner packaging is the same as or greater than the inner packaging used in the tested reference packaging. Therefore, even though the selective testing guidelines may allow a particular variation, if there is a reason to believe that the modified packaging is not able to perform at a level equivalent to that of the tested reference packaging, additional action is necessary. Such action may range from subjecting the packaging to a limited number of representative tests to assess its performance capabilities, to subjected the variant to the full regimen of tests as a new packaging design type. Documentation should be retained to support any decisions made as a result of such performance capability assessments (Richard,1990).

If feasible the changes should have technical justification and tight material specification to ensure consistent performance level. By controlling packaging material, the packager can maintain performance level without having to frequently test the package or incure high cost due to over specifying packaging material. Combination packaging material control can be made by :

(a) Always specify the exact component which was used or the package performance testing by using product number and description from reputable manufacturers.

(b) Specify dimensions and properties of the components which are related to finish product performance. For example, with corrugated board, short column strength relates to box compression strength while burst test may not, or with pressure sensitive box sealing tape, holding power to fibreboard relates to box performance while peel adhesion to steel may not (Sheehan,1990).

DOT issued a competent authority decision, defining design changes which would require retesting of combination packaging, in response to industry concerns. Its decision is based on clarifications developed during the Committee of Experts meeting, and also based on anticipated changes. Relief from testing a combination package whose design varies from a previously tested design is defined in the decision which appears in the Federal Register, 3/22/90, pages 10750-10751 (Ten Eyck,1990).

In summary, the new DOT competent authority ruling concerning the selective testing of combination packaging can reduce the amount of testing needed to comply with UN, IMO, and ICAO combination packaging requirements. The duties and responsibilities of persons applying the selective testing provisions are for the most part the same as those for persons performing any of the UN performance testing and certification functions :

(a) Read and understand all relevant provisions applicable to the product.

(b) Apply these provisions to the specific packaging requirements in such a way as to comply with them fully, while simultaneously affording maximum flexibility in packaging application with a minimal amount of re-testing.

(c) Maintain records adequate to establish what you did, why you did it, and how you concluded that the resulting packaging complied with all applicable requirements (Richard,1990).

3.1.6 Preparation of Packaging for Testing under the UN Recommendations

Tests should be carried out on packaging prepared for transport including inner packaging of combination packaging. Inner packaging should be filled to not less than 95% of their capacity for solids or 98% for liquids. The substances to be transported in the packaging may be replaced by other substances except where this would invalidate the results of the tests. For solids, when another substance is used it should have the same physical characteristics as the substances to be carried.

Paper or fibreboard packaging should be conditioned for at least 24 hours in a controlled atmosphere. There are three options, from which to chose. The preferred atmosphere is 23° ± 2°C and 50% ± 2% r.h. relative humidity. The two other options are 20°C ± 2°C and 65% ± 2% r.h. or 27° ± 2°C and 65% ± 2% r.h. (The UN Recommendations,1990). Bung-type barrels made of natural wood should be left filled with water for at least 24 hours before the tests.

Steps should be taken to ascertain that parts of packaging which are in direct contact with dangerous substances should not be affected by chemical or other action of those substances. Where necessary, they should be provided with a suitable inner coating or treatment. It should be manufactured from suitable plastics material and be of adequate strength in relation to its capacity and intended use. The packaging should be adequately resistant to aging and to degradation caused by the substance contained or by ultra-violet radiation. Any permeation of the substance contained should not constitute a danger under normal conditions of transport.

3.1.7 Test Requirements for Packaging

The design type of each package should be tested in accordance with procedures established by the competent authority. Tests should be successfully performed on each packaging design type before the packaging is used. A packaging design type is defined by the design, size, material and thickness, manner of construction and packing, but may include various surface treatments. Moreover, the test should be repeated on production samples at intervals established by the competent authority and should be repeated after each modification which alters the design, material, or manner of construction of a packaging. For hazardous material packaging testing, there are four important tests that must be done before shipping the substances.

3.1.7.1 Drop test

3.1.7.2 Leakproofness test

3.1.7.3 Internal pressure (hydraulic) test

3.1.7.4 Stacking test

3.1.7.1 Drop Test

The number of test samples and drop orientation depends on the packaging, i.e., drums, boxes, bags with seams and bags without seams. If a substitute liquid is used, it should have similar relative density and viscosity to those of the substance being transported. Test liquids should be kept in the liquid state, if necessary by the addition of antifreeze.

Test method. The packing group is used to decide the drop height. For solids and liquids (density not exceeding 1.2) test, the drop height of Packing Group I is 1.8 m. Packing Group II is 1.2 m and Packing Group III is 0.8 m. Substances that have a density exceeding 1.2, should be calculated on the basis of the relative density (d) of the substance to be carried, rounded up to the first decimal. The drop height of Packing Group I is d * 1.5 (m), Packing Group II is d * 1.0 (m), and Packing Group III is d * 0.67 (m) (The UN Recommendations,1990).

The target of a drop test should be a rigid , non-resilient, flat and horizontal surface. When a packaging for solids undergoes the drop test and its upper face strikes the target, the test sample passes the test if the entire contents are retained by an inner packaging or inner receptacle, even if the closure is no longer sift-proof. Nevertheless, the packaging or outer packaging of a composite or combination packaging should not exhibit any damage liable to affect safety during transport. There should be no leakage of the filling substance from the inner packaging (The UN Recommendations,1990).

Drums or composite packaging which are in the shape of drum require six samples, three for each drop orientations. On the first drop the packaging should strike the target diagonally on the chime or, if the packaging has no chime, on a circumferential seam or an edge. For the second drop, the package should strike the target on the weakest part not tested by the first drop such as the closure or the welded longitudinal seam of the drum body.

For boxes or composite packaging which are in the shape of a box, five samples are required, one for each drop. The first drop is flat on the bottom. The second drop is flat on the the top. The third drop is flat on the long side. The fourth is flat on the short side and the fifth drop is on a corner.

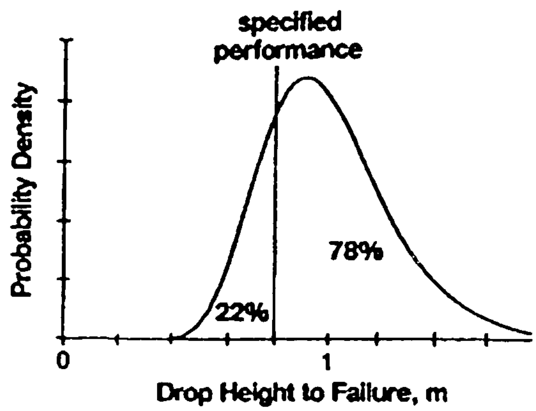
Bags (single ply) with a side seam, require three samples and three drops per bag. The first drop is flat on a wide face and the second drop is flat on a narrow face, while the third drop is on the end of the bag. For bags (single-ply or multi-ply) without a side seam, three samples, two drops per bag are required. First drop is flat on a wide face; second drop is on the end of the edge.

Criteria for passing the test for liquid containing packaging should be leakproof when equilibrium has been reached between the internal and external pressures, except for inner packagings of combination packagings.

For solid containing, packaging should not exhibit any damage liable to affect safety during transport. Both liquid and solid containing closure(s) upon impact should not be a failure of the packaging provided that no rupture and leakage occurs (The UN Recommendations,1990).

The analysis of drop test performance of an empty one gallon glass jar in a corrugated box is shown in Figure 2. This shows the distribution of drop heights at which glass breakage occurred during side drops. This test package was not designed for hazardous material shipment; it is shown only as a a real example of one package's performance. The hypothetical question involves how this package might relate to the Packing Group III requirement of 0.8 m. drop performance.

Figure 2 The Drop Height Performance of Glass Jar in Box

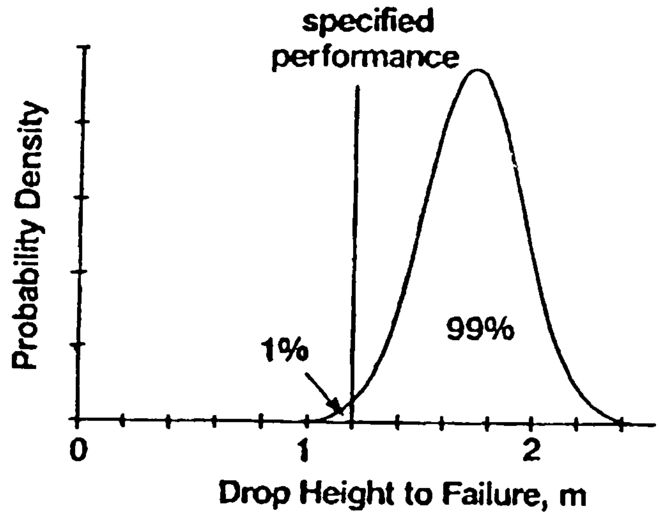


Source: From The Chemical Packaging Review, volume IX, number 1, p.17 "Implementing the United Nations Performance Standards for Packaging" by Richard Sheehan, 1990.

Analysis of this distribution indicates that about 22 % of the area of this curve is below the performance specification while 78% of package would pass the test. The UN required two packages to pass this side drop (in addition to three other packages for other orientations). About 61% of the sets of two packages would result in two successful tests. While the reliability of this package is low, there is a probability of 0.61 that a set of tests would support certification. If certification were to occur, a subsequent performance audit may (P = 0.61), or may not (P = 0.39), verify compliance.

The above example was somewhat hypothetical; this third one is much closer to reality. A set of 17E steel pails filled with water was audited for its drop performance for chime drops. Figure 3 shows that about 1 % of the pails were below the Packing Group II requirements; 99 % exceeded this requirement. These pails must pass this drop orientation; the probability is 0.97 that certification would occur. The reliability of this pail is very high but it is not 100 %; a lower confidence interval of this reliability would reduce it further.

Figure 3 The Drop Height Performance of Steel Pail



Source: From The Chemical Packaging Review, volume IX, number 1, p.16 "Implementing the United Nations Performance Standards for Packaging" by Richard Sheehan, 1990.

The exact shape of the performance curve for figure 3 is not known; the lower tail might be different than indicated by this normal distribution. A lognormal distribution would reduce the estimated percentage of failing pails but a fraction of a percent would still be below the specification. The experimental procedures and the number of samples needed to investigate this lower tail are different from those described by UN packaging specifications (Nelson,1990).

In summary, it is possible to accept a package per the UN minimum guidelines and still have a large percentage below specified performance requirements. This may be totally unacceptable per your testing requirements. In this case, it may be necessary to design a test which is superior to the UN minimum guidelines to guarantee successful shipping.

3.1.7.2 Leakproofness Test

Every packaging intended to contain liquids should undergo the leakproofness test before it is first used for transport or after reconditioning, before it is reused for transport. Packaging or receptacles should have no leakage. They require three test samples per design type and manufacturer. The vent should be sealed during the test. However, this test is not required for the inner packaging of combination packaging.

Test method. The packaging, including their closures, should be restrained under water while an internal air pressure is applied. The method of restraint should not affect the results of the test. Other methods at least equally effective may be used. The air pressure to be applied for Packing Group I should be not less than 30 kPa (0.3 bar). For Packing Group II is not less than 20 kPa (0.2 bar) and packing group III is not less than 20 kPa (0.2 bar). Criteria for passing the test should be no leakage (The UN Recommendations,1990).

3.1.7.3 Internal Pressure (Hydraulic) Test

The internal pressure test should be carried out on all metal, plastics and composite packaging intended to contain liquids. Except for air transport, this test is not required for inner packaging of combination packaging. They require three test samples per design type and manufacturer, and the vent should be sealed.

Test method. Metal packaging and composite packaging including their closures should be subjected to the test pressure for 5 minutes. Plastics packaging and composite packaging, including their closures, should be subjected to the test pressure for 30 minutes. Where the test pressure has been successfully passed, the test pressure in kPa is rounded off to the nearest 10 kPa. The manner in which the packaging are supported should not invalidate the test. The test pressure should be applied continuously and evenly, it should be kept constant throughout the test period.

The hydraulic pressure (gauge) applied by any one of the following methods should be:

(a) Not less than the total gauge pressure of the product in the packaging at 55°C, multiplied by a safety factor of 1.5. This total gauge pressure should be determined on the basis of a maximum degree of filling.

(b) Not less than 1.75 times the vapor pressure at 50°C of the substances to be transported, minus 100 kPa but with a minimum test pressure of 100 kPa.

(c) Not less than 1.5 times the vapor pressure at 55°C of the substance to be transported, minus 100 kPa but with a minimum test pressure of 100 kPa.

In addition, packaging intended to contain substances of packing group I should be tested to a minimum test pressure of 250 kPa for a test period of 5 to 30 minutes depending upon the material of construction of the packaging. Criteria for passing the test should be no leakage (The UN Recommendations,1990).

3.1.7.4 Stacking Test

All packaging other than bags should be subjected to a stacking test. This test requires three test samples per design type and manufacturer.

Test method The test sample should be subjected to a force applied to the top surface of the sample test equivalent to the total weight of identical packages which might be stacked on it during transport. Where the contents of the test sample are non-dangerous liquids with relative density different from that of the liquid to be transported, the force should be calculated in relation to the latter. The minimum height of the stacking including the test sample should be 3 meters. The duration of the test should be 24 hours except that plastics drums, jerricans, and composite packaging that are intended for liquids should be subjected to the stacking test for a period of 28 days at a temperature not less than 40°C.

The criteria for passing the test is that no test sample should leak. In composite packaging or combination packaging, there should be no leakage of the filling substance from the inner packaging. No test sample should show any deterioration which could adversely affect transport safety for packages. In cases where stacking stability is assessed after completion of the test, it may be considered sufficient when two filled packaging of the same type placed on each test sample maintain their position for one hour. Plastic packaging should be cooled to ambient temperature before the assessment.

3.2 Selection of Packaging

Limited quantity provisions which allow shippers to use non-UN marked packaging could also provide some relief from the testing burden. These provisions are never applicable for Group I materials by any mode of transport. The UN performance standards for combination packaging might pose difficulties for companies that do not have a centralized packaging department, or where occasional shipments must be made from remote locations in a company.

Even if a box bearing UN marks for tested combinations were provided, it could be difficult to convey how to configure the combination and attributes such as the amount and positioning of cushioning material. However, the person making the shipment would need to:

(a) Ensure that the outer packaging available included the same box and was configured in the same manner as the outer packaging used in the tested combination; and

(b) Compare the inner packaging with packaging used in approved combinations, based on the criteria for allowable substitutions.

According to CFR 49, section 173.24, the standard requirements for all packages used for shipping hazardous materials shall be so designed and constructed, and its contents so limited, that under conditions normally incident to transport as follows:

(a) There will be no significant release of the hazardous materials to the environment.

(b) The effectiveness of the packaging will not be substantially reduced.

(c) There will be no mixture of gases or vapors in the package which could through any credible spontaneous increase of heat or pressure, or through an explosion, significantly reduce the effectiveness of the packaging.

And also all packages, used for the shipment of hazardous materials, have to meet the standard requirements according to the UN Recommendations.

3.3 Filling and Closing Packaging

The selected packages are filled and closed in compliance with the UN Recommendations. In general, closure shall be adequate to prevent inadvertent leakage of the contents under normal conditions incident to transportation. Gasket closures shall be fitted with those of efficient material which will not be deteriorated by the contents of the container.

3.3.1 Regulation of Emptied Hazardous Materials Packaging

Under the hazardous materials regulation, CFR 49, Section 173.29, this states that emptied packaging of any size or type containing any residue of a hazardous material must be shipped as if it were full of that material. The exceptions are when that packaging has been cleaned and purged, or has been refilled with an unregulated material. The UN Recommendations, Section 9.3.11, also indicates that the safety concern is with hazardous vapors which may be a greater danger than when the packaging was full. The emptied packaging must be in proper condition for transport to ensure that all containers are truly empty and environmentally safe, i.e., not leaking, with closures tightly in place and legible marking and labeling reflecting its former contents, except for non-bulk packaging being shipped in private or contract carriage for reconditioning or reuse. These emptied containers must be accompanied by shipping papers identifying the former contents. Placarding is not required for emptied non-bulk packaging. The transportation of packaging, that has not been cleaned, in which residues of former contents may no longer be effectively contained, is described in CFR 49 Section 173.24 (Bierlein,1990).

It is very difficult to determine which containers are empty. The following are methods that many packagers use to limit their potential liability from disposal of emptied containers:

(a) Each container should be as empty as possible, not just as empty as conveniently possible.

(b) All labels and markings from the container not required by the regulation should be removed, instead of just covering them or marking over them.

(c) If the container is to be disposed of at a landfill, then the container should be crushed or cut-up after it has been rinsed. If crushing a container, especially a drum, a crusher that flattens it from end to end should be used. Containers that are partially crushed from the sides are usually regarded by government investigators as a container that may have arrived filled and was crushed by conditions in the landfill.

(d) Establish a written company policy towards handling emptied containers, then ensure that the policy is followed by the assignment of authority and responsibility for the policy. Train the workers on how to remove the contents completely, and have them certify that each load of empty containers are sent out empty (Prothero,1990).

In conclusion, personal in charge of emptying any type or size of packaging should consider the residues remaining in the packaging, and confirm that it is being managed properly under the regulations of the DOT.

3.4 Marking and Labeling

The marking and labeling are intended to help packaging manufacturers, reconditioners, packaging users, carrier and regulatory authorities to identify the type of packaging, its maximum capacity and/or mass, any special requirements and to indicate that performance test recommendations have been met .

3.4.1 Marking

Marking means those letters, numbers, words and symbols that DOT requires to be marked on hazardous materials packages. Generally, the type of packaging, its maximum capacity and/or mass, and any special requirements are specified for each substance in the regulations for each mode of transport. All marking must be in English, must be legible, must be placed on a contrasting background, and may not be near any other marking that could reduce its effectiveness substantially. Marking does not refer to those marks on containers that are applied by a shipper or a carrier for his own purposes or other government regulations.

There are several types of marking which appear on most hazardous materials containers:

(a) Marking to be applied by a packaging manufacturer or reconditioner.

(b) The shipper's marking of the name of contents.

(c) An indication that a "reportable quantity" or "RQ" of a hazardous substance is contained in the package.

(d) Special markings on portable tanks.

(e) Cargo tanks.

(f) Tank cars.

(g) Certain miscellaneous series of advisory messages, e.g.,"This Side Up" and other information such as the name and address of the consignee under certain circumstances (Bierlein,1988).

The marking do not provide full details of the test levels, and these may need to be taken into account by reference to a test certificate, test reports or a register of successfully tested packaging (The UN Recommendations,1990).

3.4.1.1 Examples and Markings Explained

Examples of markings for NEW packaging:

4G/Y145/S/83	as in paragraph (a), (b), (c), (d) and (e) which follow	For a new fibreboard box
NL/VL823	as in (f) and (g)	
1A1/Y1.4/150/83	as in (a), (b), (c), (d) and (e)	For a new drum to contain liquids
NL/VL824	as in (f) and (g)	
1A2/Y150/S/83	as in (a), (b), (c), (d) and (e)	For a new steel drum to contain solids, or inner packaging
NL/VL825	as in (f) and (g)	
4HW/Y136/S/83	as in (a), (b), (c), (d) and (e)	For a new plastics box of equivalent specification
NL/VL826	as in (f) and (g)	

According to these examples, the UN Recommendations state that each package should bear durable and legible marking with a visible size from the following explanations;

(a) The United Nations packaging symbol appears below.

This must not be used for any purpose other than certifying that a packaging complies with the relevant recommendations. For embossed metal packaging the capital letters "UN" may be applied as the symbol.

(b) The code number designs the type of packaging according to table 4.

Table 4 Types and Codes of Packaging:

Type	Code	Category	Maximum		Air[5]
1			capacity (litres)	net mass (kg)	
Steel drums	1A1	non-removable head	450	400	
	1A2	removable head	450	400	
Aluminium drums	1B1	non-removable head	450	400	
	1B2	removable head	450	400	
Steel jerricans	3A1	non-removable head	60	120	
	3A2	removable head	60	120	
Plywood drums	1D		250	400	
Wooden barrels	2C1	bung type	250	400	2
	2C2	slack type (removable head)	250	400	3
Fibre drums	1G		450	400	

[5] Note The last column (air) signified:

1. packaging has not yet been used in the air transport regulations;
2. packaging is not used in the air transport regulations;
3. packaging has only specialized use in the air transport regulations.

Plastics drums	1H1	non-removable head	450	400	
	1H2	removable head	450	400	
Plastics jerricans	3H1	non-removable head	60	120	
	3H2	removable head	60	120	
Boxes of natural wood	4C1	ordinary		400	
	4C2	with sift-proof walls		400	
Plywood boxes	4D			400	
Reconstituted wood boxes	4F			400	
Fibreboard boxes	4G			400	
Plastics boxes	4H1	expanded plastics boxes		60	
	4H2	solid plastics boxes		400	
Steel boxes	4A1			400	
	4A2	with inner liner or coating		400	
Aluminium boxes	4B1			400	1
	4B2	with inner liner or coating		400	1
Textile bags	5L1	without inner liner or coating		50	2
	5L2	sift-proof		50	
	5L3	water-resistant		50	
Woven plastics	5H1	without inner liner or coating		50	3

bags	5H2	sift-proof		50	
	5H3	water-resistant		50	
Paper bags	5M1	multiwall		50	2
	5M2	multiwall, water resistant		50	3
Composite packaging	plastics receptacle with outer:				
(plastic material)	6HA1	steel drum	250	400	
	6HA2	steel crate* or box	60	75	
	6HB1	aluminium drum	250	400	
	6HB2	aluminium crate * or box	60	75	
	6HC	wooden box	60	75	
	6HD1	plywood drum	250	400	
	6HD2	plywood box	60	75	
	6HG1	fibre drum	250	400	
	6HG2	fibre board box	60	75	
	6HH	plastics drum	250	400	
Composite packaging	glass, porcelain or stoneware				
(glass, porcelain or		receptacle with outer:			
stoneware)	6PA1	steel drum	60	75	2
	6PA2	steel crate* or box	60	75	2
	6PB1	aluminium drum	60	75	2
	6PB2	aluminium crate*or box	60	75	2
	6PC	wooden box	60	75	2
	6PD1	plywood box	60	75	2
	6PD2	wickerwork hamper	60	75	2
	6PG1	fibre drum	60	75	2
	6PG2	fibreboard box	60	75	2

6PH1	expanded plastics packaging	60	75	2
6PH2	solid plastics packaging	60	75	2

* Crates are outer packaging with incomplete surface and are not acceptable for air transport.

(c) A code in two parts:

(1) a letter designates the packing group(s) for which the design type has been successfully tested:

X for Packing Groups I, II and III

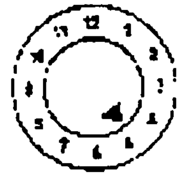
Y for Packing Groups II and III

Z for Packing Groups III only;

(2) the relative density, rounded off to the first decimal, for which the design type has been tested for packaging without inner packaging intended to contain liquids; this may be omitted when the relative density exceeds 1.2. For packaging intended to contain solids or inner packaging, the maximum gross mass in kilograms;

(d) Either a letter "S" denoting that the packaging is intended for the transport of solids or inner packaging, or, where a hydraulic pressure test has been successfully passed, the test pressure in kPa rounded off to the nearest 10 kPa;

(e) The last two digits of the year during which the packaging was manufactured. Packaging types 1H and 3H should also be approximately marked with the month of manufacture; this may be marked on the packaging in a different place from the remainder of the marking. An appropriate method is:



(f) The country of original authorizing the allocation of the mark, indicated by the distinguishing sign for motor vehicles in international traffic;

(g) The name of the manufacturer or other identification of the packaging specified by the competent authority (The UN Recommendations,1990).

Marking should be applied in the sequence (a) to (e). Any additional markings authorized by a competent authority must still enable the parts of the mark to be correctly identified with reference (a) to (g).

Every reusable packaging liable to undergo a reconditioning process which might obliterate the packaging markings should bear the marks indicated in (a) to (e), in a permanent form able to withstand the reconditioning process.

Examples of markings for RECONDITIONED packaging

1A1/Y1.4/150/83	as in I (a), (b), (c), (d) and (e)
NL/RB/85 RL	as in IV (h), (i) and (j)

1A1/Y1.4/150/83	as in I (a), (b), (c), (d) and (e)
NL/VL824	as in I (f) and (g)
NL/RB/85 RL	as in IV (h), (i) and (j)

1A2/Y150/S/83	as in I (a), (b), (c), (d) and (e)
USA/RB/85 R	as in IV (h), (i) and (j)

After reconditioning a packaging, the reconditioner should apply to it, in sequence, a durable marking showing:

(h) The State in which the reconditioning was carried out, indicated by the distinguishing sign for motor vehicles in international traffic;

(i) The name or authorized symbol of the reconditioner;

(j) The year of reconditioning; the letter "R"; and, for every packaging successfully passing the leakproofness test, the additional letter "L".

The markings referring to reconditioned packaging marking should be applied new packaging marking, and may replace that of (f) and (g) or be in addition to that marking.

3.4.2 Labeling

Labels take the form of a square set at an angle of 45° diamond-shape with minimum dimensions of 100 mm by 100 mm, except in the case of packages of such dimensions that they can only bear smaller labels. The labels are intended for affixing on goods or packages. The labelling system is based on the classification of dangerous goods and was established with the following aims in mind:

(a) To make dangerous goods easily recognizable from a distance by the general appearance (symbol, color and shape) of the labels they bear.

(b) To make the nature of the risks easy to identify by means of symbols. The five main symbols: Bomb (Explosion), Flame (Fire), Skull and Crossbones (Poisons), Trefoil (Radioactivity), Liquids spilling from two glass vessels and attacking a hand and a metal (Corrosion), are supplemented by five others to indicate oxidizing substances (a flame over a circle), non-flammable compressed gases (a gas cylinder), infectious substances (three crescents superimposed on a circle), harmful substances which should be stowed away from foodstuffs and miscellaneous dangerous substances; and

(c) To provide, by means of colors on the labels, a useful first guide for handling and stowing (The UN Recommendations,1990).

In general, not more than one danger class label should be affixed to a package. However, since a substance or material may present more than one significant risk, the package should bear in addition to the label corresponding to the primary risk such additional label(s) as would indicate important subsidiary risks.

If a substance which meets the definition of more than one class is not specifically listed by name, the Precedence of Hazard Characteristics Table (Table 3) should be used to determine the primary hazard class of the goods. In addition to the label required for the primary hazard class, subsidiary risk labels should also be applied in accordance with table 5. Table 5 is equally applicable when incorporating a new substance with multiple risks.

Table 5 Subsidiary Risk Labels

Subsidiary risk	Class or Division						
hazard level	3	4.1	4.2	4.3	5.1	6.1	8
Packing Group							
I	X	***	***	X	X	X	X
II	X	X	X	X	X	X	X
III	*		X	X			**

X Required for all modes

* Required for sea mode only

** Required for air and sea modes only

*** Impossible as a subsidiary risk

Class 8 substances need not carry a subsidiary risk label of 6.1 if the toxicity arises solely from the destructive effect on tissue. Substances of Division 4.2 need not carry a subsidiary risk label of 4.1.

In all instances where subsidiary risk labels are applied, only the label identifying the primary hazards of the goods should bear, in the lower corner of the label, the number of the class or division as appropriate, while labels identifying subsidiary risks should bear no class or division number (The UN Recommendations,1990).

Labels should be placed on a background of contrasting color. All labels should be able to withstand open weather exposure without a substantial reduction in effectiveness. The additional marking or symbols also indicating precautions to be taken in handling or storing a package may be displayed on a package if appropriate, e.g. a symbol representing an umbrella indicating that a package should be kept dry.

For sea transportation, markings and labels should be identifiable on packages surviving at least three months immersion in sea water. Packages should bear the proper shipping name of the dangerous substances. The proper shipping name should be followed by the recognized chemical name. Packages should also bear the labels of the individual Classes. The packaging identification codes will be added next to the label.

For air transportation, markings and labels must be permanent, i.e., capable of withstanding open weather exposure. They must not be covered or obscured. Each package or overpack must be labelled with :

(a) The proper shipping name, followed by the recognized chemical name.

(b) The assigned UN serials number. The IATA DGR provide identification numbers. The former numbers should be included, when there is no number.

(c) The appropriate hazard labels described in the individual classes.

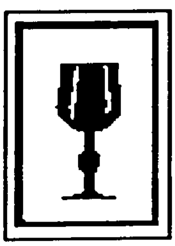
(d) When the dangerous goods contained in the package may only be transported in cargo aircraft.

(e) Combination packages containing liquid dangerous goods, except flammable liquids in inner packaging of 120 ml or less, must bear the "package orientation label" (Mostyn,1986).

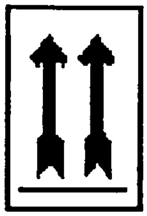
For RID/ADR transportation, the regulations do not require the name of the substance to be marked on the package, nor the Class number to be included in primary hazard labels. The RID/ADR regulations refer to the labels by model numbers. Required labels are as follows:

(a) Packages containing fragile receptacles not visible from the outside shall bear the wineglass labels.

(b) Packages containing liquids in receptacles the closures of which are not visible from the outside and packages containing vented receptacles or vented solo packages shall bear the two black upward arrows labels.



Red wine glass on white blackground labels fixed on two opposites sides of the package.



Two black arrows on white background. Labels fixed with arrow upward high on two opposite sides of the package.

If substances are packed in composite packaging (glass, porcelain or stoneware) with capacities greater than 5 L, the package shall bear these two labels. If mixed packaging is used, the collective package shall bear the markings and labels prescribed for the dangerous substances in the collective package.

3.4.3 Case Study

This case study shows the basic steps for shipping hazardous materials according to CFR 49 Section 172.102 (See Table 6 - the Hazardous Materials Table). The substance to be shipped in this example is Ethylbenzene.

Ethylbenzene is required by DOT to bear the label, "Flammable liquid." This is its classification for DOT's purposes. Part of the task of shipping hazardous materials is to determine the proper shipping name for a material. If the proper name of the substance cannot be found in DOT's alphabetical commodity list, then the chemical component or the generic ingredients of substance should be checked. For example, what is a liquid cleaning agent composed of phosphoric acid, acetic acid, and water? How should it be classified? Most mixtures of materials are not listed by a specific chemical name in the commodity list. So, the chemical components of the mixture should be checked for their classification. The phosphoric acid in this particular mixture is individually classed as a corrosive material. (Perhaps the mixture itself may be corrosive.) The other basic component of the mixture is acetic acid. Acetic acid appears in the commodity list. It is classed as an aqueous solution which is also a corrosive material. So, these two components of the mixture are classed as corrosive materials. A definitive resolution of the question depends upon the performance of the substance in specified testing, described in DOT regulations as part of the definition of the corrosive materials classification. If the shipper has received the material in its present form from a supplier, it is likely that the supplier has already performed the necessary tests and has determined its DOT classification. If the supplier does not know the results of rabbit skin and metal corrosion tests, it will be necessary to contract with an outside laboratory to perform them. If testing shows that this mixture is a corrosive material, and that is its classification for DOT purposes.

The UN 1175 is the identification number of Ethyl benzene. As a flammable liquid, ethylbenzene must bear a four-inch-by-four-inch red color diamond with flame symbol, inscription, and border in black. The label should be conspicuous, and it must be placed on the package near the DOT-required marking of the name of the contents of that package. The shipper is responsible for correct labeling.

The packaging column is divided into 2 columns: (a) exceptions and (b) specific requirements. These section numbers list exceptions to the regulations that otherwise list the particular range of packaging authorized for that commodity. The exceptions of Ethyl benzene is 173.118 and the specific requirement is 173.119. In Section 173.118 states that if the limited quantity the shipper wants to send is greater than that for which exception is granted, then it is necessary to turn to Section 173.119 to determine the authorized packaging. Section 173.119 offers a variety of sizes for specific packaging design. Each DOT specification in Section 173.119 is combined with a sectional reference to the detailed package construction requirements in Section 178 of the regulations. The shipper determines the packaging size, selecting from among the specifications authorized for that materials.

The maximum quantity in one package that passenger cargo, aircraft or railcar can carry and the maximum quantity that can be shipped by aircraft cargo or water shipments is listed by the DOT (CFR49 Section 172.101).

However, all packages for hazardous materials must satisfy the general packaging requirements contained in CFR 49 Section 173.24, entitled "Standard Requirements for All Packages." Perhaps other packagers who ship the same materials, can share their knowledge of the proper safety precautions; trade associations also have helpful publications on the subject.

Table 6 Hazardous Materials Table (CFR 49 Section 172.102)

(1) Notes and Symbols	(2) Hazardous Materials Description and Proper Shipping Names	(3) IMCO Class	(4) Identification Number	(5) Label(s) required	(6) Packaging Group	(7) Vessel Stowage Requirements (a) Cargo vessel	(b) Passenger vessel	(c) Other requirements
	Dithiocarbamate pesticides, liquid, flammable, toxic, n.o.s., *flash-point less than 23 deg C*	3.2	UN 2772	Flammable Liquid and Poison or St. Andrews Cross (according to toxicity)	I/II	1,2	1	
	Dithiocarbamate pesticides, liquid, toxic, flammable, n.o.s., *flash-point between 23 deg C and 61 deg C*	6.1	UN 3005	Poison, Flammable Liquid	I	1	1	Segregation same as for flammable liquids
		6.1	UN 3005	Poison, Flammable Liquid	II	1,2	1	Segregation same as for flammable liquids
		6.1	UN 3005	St. Andrews Cross, Flammable Liquid	III	1,2	1,2	Segregation same as for flammable liquids
	Dithiocarbamate pesticides, liquid, toxic, n.o.s.	6.1	UN 3006	Poison	I	1	1	
		6.1	UN 3006	Poison	II	1,2	1	
		6.1	UN 3006	St. Andrews Cross	III	1,2	1,2	
	Dithiocarbamate pesticides, solid, toxic, n.o.s.	6.1	UN 2771	Poison	I/II	1,2	1,2	
		6.1	UN 2771	St. Andrews Cross	III	1,2	1,2	
	Di-(3,5,5-trimethyl-1,2-dioxolanyl-3)peroxide, *as a paste with at least 50% phlegmatizer*	5.2	UN 2597	Organic Peroxide	II	1	5	Control temperature 30 deg C. Emergency temperature 35 deg C
	Di-(3,5,5-trimethylhexanoyl)peroxide, *technical pure or in solution*	5.2	UN 2128	Organic Peroxide	II	1	5	Control temperature 0 deg C. Emergency temperature 10 deg C
	Divinyl ether, inhibited	3.1	UN 1167	Flammable Liquid	II	1,3	5	Keep cool
	Dodecyl trichlorosilane	8	UN 1771	Corrosive	II	1	1	Keep dry
	Dressing, leather. *See* Flammable liquid preparations, n.o.s.							
	Driers, *paint or varnish*, liquid, n.o.s.	3.2	UN 1168	Flammable Liquid	II	1,2	1	
		3.3	UN 1168	Flammable Liquid	II	1,2	1,2	
	Driers, *paint or varnish*, solid, n.o.s.	4.1	UN 1371	Flammable Solid	III	1,2	1,2	
	Dyes, n.o.s. *or* Dye intermediates, n.o.s., *liquid or solid, corrosive*	8	UN 2801	Corrosive, Flammable Liquid (only if flashpoint between 23 and 61 deg C)	II/III	1,2	1,2	Segregation same as for flammable liquids, if flashpoint between 23 and 61 deg C
	Ethane, *compressed*	2.1	UN 1035	Flammable Gas	–	1,2	5	
	Ethane, *refrigerated liquid*	2.1	UN 1961	Flammable Gas	–	1	5	
	Ethanolamine *or* Ethanolamine solutions	8	UN 2491	Corrosive	III	1,2	1,2	
	Ethanol *or* Ethaonl solutions *including* Alcoholic beverages	3.2	UN 1170	Flammable Liquid	II	1,2	1	
		3.3	UN 1170	Flammable Liquid	III	1,2	1,2	
	Ether. *See* Diethyl ether							
	Ethyl acetate	3.2	UN 1173	Flammable Liquid	II	1,2	1	
	Ethyl acetylene, inhibited	2.1	UN 2452	Flammable Gas	–	1	5	
	Ethyl acrylate, *inhibited*	3.2	UN 1917	Flammable Liquid	II	1,2	1	
	Ethyl alcohol. *See* Ethanol							
	Ethyl aldehyde. *See* Acetaldehyde							
	Ethyl aluminium dichloride	4.2	UN 1924	Spontaneously Combustible	I	1	1	
	Ethyl aluminium sesquichloride	4.2	UN 1925	Spontaneously Combustible	I	1	1	
	Ethylamine	2.1	UN 1036	Flammable Gas	–	1,2	5	
	Ethylamine solution *in water, concentrations up to 70%*	3.1	UN 2270	Flammable Liquid	II	1,3	5	Keep cool
		3.2	UN 2270	Flammable Liquid	II	1,2	1,2	
		3.3	UN 2270	Flammable Liquid	III	1,2	1,2	
	Ethyl amyl ketone	3.3	UN 2271	Flammable Liquid	III	1,2	1,2	
	N-Ethylaniline	6.1	UN 2272	St. Andrews Cross	III	1,2	1,2	Stow 'away from' acids
	2-Ethylaniline	6.1	UN 2273	St. Andrews Cross	III	1,2	1,2	
	Ethylbenzene	3.2	UN 1175	Flammable Liquid	II	1,2	1,2	
	N-Ethyl-n-benzylaniline	6.1	UN 2274	St. Andrews Cross	III	1,2	1,2	Stow 'away from' living quarters
	N-ethylbenzyltoluidines	6.1	UN 2753	St. Andrews Cross	III	1,3	1,3	Keep cool
	Ethyl borate	3.2	UN 1176	Flammable Liquid	II	1,2	1	
	Ethyl bromide	6.1	UN 1891	Poison	II	1,3	1	Stow 'away from' sources of heat
	Ethyl bromoacetate	6.1	UN 1603	Poison, Flammable Liquid	II	1	5	Stow 'away from' living quarters. Segregation same as for flammable liquids
	2-Ethylbutanol	3.3	UN 2275	Flammable Liquid	III	1,2	1,2	
	Ethylbutyl acetate	3.3	UN 1177	Flammable Liquid	III	1,2	1,2	
	Ethyl butyl ether	3.2	UN 1179	Flammable Liquid	II	1,2	1	
	2-Ethylbutyraldehyde	3.2	UN 1178	Flammable Liquid	II	1,2	1	
	Ethyl butyrate	3.3	UN 1180	Flammable Liquid	II	1,2	1,2	
	Ethyl chloride	2.1	UN 1037	Flammable Gas	–	1,2	5	Stow 'away from' living quarters

3.5 Paper and Document Requirements

Shipping papers are required by DOT for hazardous materials transportation. All shipments must be accompanied by shipping papers given to the carrier. The carrier is obligated to have certain information at hand regarding the nature of the hazardous materials aboard the transport vehicle.

DOT requirements for shipping papers:

1. The proper shipping name of each different hazardous material in the shipment, as described in CFR 49 172.101 or 172.102.
2. The classification prescribed for each different hazardous material, as it is paired with the proper shipping name in the applicable column of the alphabetical commodity list.
3. The United Nations (UN) or North American (NA) identification number for this shipping name and class, as given in the commodity list (See Table 6).
4. The total quantity of each different hazardous material in the shipment by weight, volume, or some other appropriate means (The quantity may precede the shipping name).
5. If the shipment contains a reportable quantity of a hazardous substance, the initials "RQ" either preceding or following the shipping description.
6. The shipping paper must also include a signed certificate worded as follows: "This is to certify that the above-named materials are properly classified, described, packaged, marked, labeled, and are in proper condition for transportation, according to the applicable regulations of the Department of Transportation" (Bierlein,1988).

The certificate on the shipping paper must be signed by the shipper. The signature does not need to be placed in immediate proximity to the certificate. A signature in any location on the document is sufficient to comply with the DOT requirements. The exact nature of the signature has been a frequent source of question and controversy. The signature may be manual, typewritten, computer-printed, facsimile stamped, or applied by other mechanical means. In air transportation under IATA, a typewritten signature is not acceptable. In addition, the signature must refer to a person as an identifiable individual within the company. The company name alone is insufficient and the mere initials of an individual are not acceptable (Bierlein,1988). The person whose name appears as the signature must be fundamentally knowledgeable of the hazardous materials regulations.

When a hazardous material and nonhazardous material are described on the same shipping paper, the hazardous material must be entered first, or must be entered in a contrasting color, or must be identified by an "X" placed before the proper shipping name in a column captioned "HM". Entry of hazard information on the back of the shipping paper is also forbidden. The primary purpose of the DOT shipping paper requirement is to communicate readily the specific nature of the hazardous materials to fireman, police, and other emergency response crews. Legibility and clarity in that communication are essential (Bierlein,1988).

For shipment by air, the certificate must add the following sentence to the basic certificate: "This shipment is within the limitations prescribed for passenger cargo/air-craft only" if applicable (Bierlein,1988). The ICAO Technical Instructions require that a dangerous goods transport document must be completed and signed; details of the information required are included. The IATA/DGR refers to the dangerous goods transport document as the "Shippers Declaration for Dangerous Goods" and provide details of the form to be used together. The ICAO Technical Instructions require that the air waybill also contain the words "Dangerous Goods as per Attached Dangerous Goods Transport Document" while the IATA DGR require "Dangerous Goods as per Attached Shippers Declaration."

In rail operations, when the shipping paper is a switching ticket prepared by the shipper, the document must also bear the appropriate placard endorsement as it appears below. Also an intermediate shipper or carrier who tenders any trailers, semi-trailer, or freight container to a rail carrier must show a description of a vehicle or freight container and the kind of placards that are affixed (Table 7).

Table 7 The Kind of Placards That are Affixed at Hazardous Materials Containers

Hazardous Material or Class	Placard Endorsement	Placard Notation*
Explosives, Class A	Explosives	EXPLOSIVES A
Explosive chemical ammunition containing class A poison gas	Explosives and Poison Gas	EXPLOSIVES A and POISON GAS
Explosives, Class B	Dangerous	EXPLOSIVES B
Explosives, Class C	Dangerous	FLAMMABLE
Blasting agents	Dangerous	BLASTING AGENTS
Flammable liquids	Dangerous	FLAMMABLE
Flammable solids	Dangerous	FLAMMABLE SOLID
Oxidizers	Dangerous	OXIDIZERS
Corrosive materials	Dangerous	CORROSIVE
Nonflammable gases	Dangerous	NON-FLAMMABLE GAS
Flammable gases	Dangerous	FLAMMABLE GAS
Poisonous gases or liquids, Class A	Poison Gas	POISON GAS
Poisons, Class B	Dangerous	POISON
Irritating materials	Dangerous	DANGEROUS

Organic peroxides	Dangerous	ORGANIC PEROXIDE
Radioactive materials with radioactive yellow-III label	Radioactive Material	RADIOACTIVE
Combustible liquids	None	COMBUSTIBLE
Chlorine	Dangerous	CHLORINE
Fluorine	Dangerous	POISON
Oxygen, cryogenic liquid*	Dangerous	OXYGEN
Empty tank cars last containing hazardous material other than a combustible liquid	Dangerous	See CFR 49 174.25 (C)

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* The word "Placarded" must precede the notation on the switching tickets except when using the last notation ("EMPTY").

Source: From Red Book on Transportation of Hazardous Materials, second Edition, by Lawrence W. Bierlein, p. 133-134, 1989.

3.5.1 Penalties

A shipper of hazardous materials has the primary obligation to identify the material as hazardous and to assign it the proper transportation hazard classification. The shipper also must determine the proper description for the material and select the right packaging, marking, labeling, documentation, and placarding for the shipment.

A carrier is obligated to accept only materials that are properly prepared for transportation and to ensure that the shipping documents are in order. The carrier also must handle the shipment properly, must load it on the vehicle or vessel in accordance with stowage charts, and must deliver the cargo without unnecessary delay to the next carrier or to the consignee. The carrier also is obligated to comply with DOT's Motor Carrier Safety Regulations, CFR 49 Section 387-397. These deal with liability insurance, operating equipment, driver qualifications, hours of service, and other operations requirements (Bierlein,1989).

The regulations limit the quantity of hazardous material which can be handled in one package or shipment, depending upon the degree of toxicity, concentration, flammability, etc. The inner containers that must be used are named and the regulations specify the materials, construction of the shipping container, and required interior parts. They also indicate whether a color label, any printed precautions, and other markings are required, and place certain responsibilities on the carrier for proper handling and transportation.

Section 110 of the Hazardous Materials Transportation Act (HMTA) sets forth the enforcement mechanism for hazardous materials violations. DOT's civil penalty is administered entirely within the agency, without the involvement of the court system or the Justice Department unless it is necessary for the government to initiate a collective action. The penalties are applicable to those persons who "have knowingly committed an act which is a violation of a provision of this title or of a regulation issued under this title....." (Bierlein, 1989). Nevertheless, if a person is in possession of his senses, it is likely that he is aware of his direct acts. If the person did not know they were dealing with a hazardous material (such as a carrier who has not been so advised by a shipper), this lack of knowledge may be a valid defense.

The second sentence in Section 110 (a) states that shippers and carriers are subject to civil penalty liability of up to $10,000 for each violation, "and if any such violation is a continuing one, each day of violation constitutes a separate offense." The third sentence is applicable only to the packaging industry, but does not contain a continuing violation provision. Congress said this because at $10,000/day, most packaging businesses would lose too much money and go bankrupt.

Under a civil penalty procedure, the agency determines the amount of the penalty that could be assessed (up to $10,000 per violation), and in compromise proceedings with the company involved, effort is made to agree on the figure that will be assessed. In determining the amount of the penalty the agency must take into account the nature, circumstances, extent, and gravity of the violations committed, the degree of culpability, any history of prior offenses, ability to pay, effect on ability to continue to do business, and such other matters as justice may require (Bierlien,1989).

In criminal penalties, the HMTA also authorizes criminal sanctions of up to $25,000 or five years, or both. The criminal penalties are carefully circumscribed, however, by making them applicable only to violations willfully committed. This phrasing, indicating that there must be a willful violation as opposed to a knowing act that happens to be a violation, involves a more substantial burden on the part of the prosecution in showing intent to violate the law (Bierlein,1989).

The best thing to do about any enforcement of any regulations is to expect it to happen sometime, and to prepare for it. The best preparation is to establish a written procedure that is made part of the operational manual for the site and is incorporated in the company's training program for all new employees. There should be a procedural manual to guide employees on what to do. The company's procedural manual should be consistent, for all sites and all inspectors. Fortunately, many federal enforcement programs are similar, and effective preparation for one will be helpful for another.

SECTION 2

4.0 DOCKET HM-181

Docket HM-181--Performance Orientated Packaging Standards-- is the DOT amendment to CFR 49 to replace the existing packaging material and instruction specifications and bring CFR 49 in line with the UN Recommended Standards. This provision covers packages less than or equal to 450 liters in capacity and having net weights less than or equal to 400 kg. The test standards, contained in the document, joins existing ASTM test standards and the UN Recommendations with the objective of achieving repeatability and reproducibility in laboratory testing of packaging. HM-181 also eliminates the need to maintain complicated regulations concerning both CFR 49 and the UN recommendations. This will give packagers and shippers the opportunity to reduce cost and enhance safety.

One area changed in HM-181 are the requirements for the reuse, reconditioning and remanufacturing of non-bulk packages including a provision which expressly prohibits the reuse of packaging made of paper, plastic film, or textile. These amendments, which will be mandatory on October 1, 1996, require that shippers have to retest each package, including a leakproof test, prior to reuse. This compares to the old regulations which allowed the reuse of some containers without retesting or reconditioning.

Under the new provisions, any packaging to be reused must conform exactly to the design type originally tested and certified, including the closure devices used in the design certification process. The reuser must assume the responsibility to decide that the packaging is still capable of meeting all applicable performance tests. Packagings may not be reused if inspection identifies any incompatible residue, rupture or other damage which reduces the packaging's structural integrity.

For reconditioning packagings, the reconditioner must certify that the packaging complies with all requirements to which it was required to comply when new, including the capability to pass the applicable performance tests at the performance levels indicated by the markings applied to the packaging by the original manufacturer. Under HM-181 a reconditioner assumes much more responsibility than the old regulations.

For remanufactured packaging, all the requirements that apply to a packaging manufacturer apply to a remanufacturer. This includes defining and performance testing a design type for each packaging produced, periodic retesting, maintenance of records and test reports and the marking of packagings (Altemos,1991).

Another area HM-181 has changed is the classification scheme under CFR 49 Section 173. The new classes are as follows:

Class 1 Explosives, which are subdivided into parts 1.1 through 1.6

Class 2 2.1 Flammable Gas

2.2 Non-flammable, Non-poisonous compressed gas (also including compressed gas, liquified gas, pressurized gas, pressurized cryogenic gas, and compressed gas in solution)

2.3 Poisonous gas

Class 3 Flammable Liquids and Combustible Liquids

Class 4 4.1 Flammable Solid

4.2 Spontaneously Combustible

4.3 Dangerous When Wet

Class 5 5.1 Oxidizer

5.2 Organic Peroxide

Class 6 6.1 Poisonous Material

6.2 Infectious Substance

Class 7 Radioactive Materials

Class 8 Corrosive Materials

Class 9 Miscellaneous Materials

ORM-D Consumer Commodity, reclassification exceptions

(Herodes,1991).

Furthermore, HM-181 changes use of international standards for shipping hazardous materials by air, and shippers need to recognize that their ability to use the ICAO/IATA standards is controlled by DOT. They made these changes in the conditions authorizing use of domestic and international air regulations to reduce the differences between US and international standards. The DOT also amended five of its variations to reflect changes contained in the hazardous materials regulations by air as follows:

(a) Hazardous materials (USG-01). This variation is designed to advise international shippers of the US requirements applied to the hazardous materials. This variation have been made to delete references to ORM-A materials.

(b) Highway Transportation (USG-12). This variation gives information about the requirements for using the hazardous materials transport document as shipping papers for transporting hazardous materials by motor vehicle to and from an airport in connection with air transportation. This variation eliminates requirements to show the closeset corresponding DOT hazard class.

(c) Loading Limits (USG-19). This variation applies the requirements of the "50-pound rule" to international operations to and from the US. This usually affects passenger aircraft more than freighter operations. Until HM-181 was issued classes without limit from the 50 pound limit in CFR 49 Section 175.75 were radioactive materials and Other Regulated Materials (ORMs) both of which had no weight limit. The non-flammable compressed gases permitted aboard passenger aircraft were also accepted in quantities up to 150 pounds in addition to other classes of materials.

(d) Lithium Batteries (USG-25). DOT used to approve limited lithium batteries to cargo aircraft only. HM-181 changed this requirement and stated that unless excepted by Special Provision A45, lithium batteries may be transported on a routine basis by cargo aircraft only. However, DOT approval is still required for transporting rechargeable lithium batteries.

(e) Toxic by Inhalation (USG-34). This variation was issued to reflect the very stringent packaging and approval requirements for moving liquids toxic by inhalation. Under HM-181 has been amended to reflect the prohibition in air transportation of liquids and gases that are toxic by inhalation (Elkin,1991).

In summary, HM-181 increases the responsibility of the shippers and related users of the regulations to exercise judgement and discretion in fulfilling their regulatory responsibilities. It is important to understand the revised regulations and all associated implications, and to begin to plan for an orderly and sound transition to the new requirements.

5.0 ASTM D-4919

ASTM D-4919 is the Standard Specification for Testing Hazardous Material Packagings. The specification is under the jurisdiction of ASTM committee D-10 on packaging and is the direct responsibility of subcommittee D10.21 on shipping container environment. It covers the testing of packagings, to United Nations standards (Chapter 9), intended for transportation which meets only the performance standards established for international transportation of hazardous materials, and is based on UN Recommendations (ASTM Standards on Packaging, 1991).

Packages successfully tested to this specification may not meet national regulatory requirements nor withstand the north American distribution environment. It is therefore strongly recommended that tests, D-4169 for assurance level one, be carried out to further establish suitability of the package (ASTM Standards on Packaging, 1991).

ASTM standard clarifies some of the vague language in UN Chapter 9. Specifically, it attempts to be more detailed in such areas as:

(a) Filling and closure procedures

(b) Compatibility test

(c) Other tests

In summary, ASTM D-4919 cautions the users to consider additional tests to meet standard container minimum requirements and suggests test procedures based on shipping experience. Moreover, ASTM D-4919 improves packaging technology, and good engineering practice and clarifies some of the vague language in UN Chapter 9.

6.0 TESTING PROBLEMS WITH HAZARDOUS MATERIALS PACKAGING

There have always been in consistencies within the CFR 49 testing requirements. For example, the specification for fiberboard boxes sets out in detail the types of material required in terms of basis weight and bursting strength, but not in terms of materials specifications. For corrugated fiberboard, the specifications specify requirements for single wall or double wall construction. Specifications also state the maximum gross weights, the styles permitted, and means of closure, but, for the most commonly used standards, no testing of the complete package is required. The specifications for any given box type are very conservatively based on permitted gross weights (lading and packaging). These gross weights are less than those permitted in carrier regulations for non-hazardous materials.

Some tests of completed packages were required, such as those specified for special 12B boxes, either in the 12B standard or in the packaging requirement for a particular hazardous material. These tests were used for applications which might not have been thought suitable for fiber boxes, commonly where wooden boxes have been used. Typical applications requiring testing for boxes included fuses (railroad flares) with spikes (two drops onto a solid surface from a height of four feet, to strike diagonally with the spikes in a downward position), liquid organic peroxides in 15 mil wall thickness inner polyethylene bottle (two drops onto solid concrete from a height of four feet), and battery electrolyte in plastic bags (drop from four feet onto concrete, flat on the bottom, and flat on the largest face, one drop per box).

Test descriptions of this sort are so vague that two testing laboratories can come up with different test results for the same package, both complying completely with the test requirements as specified.

In the first example, the exact meaning of a diagonal drop is open to interpretation. For example, is this drop performed so that an edge is impacted? If so, which one of the four edges (such as the bottom-end edge, the top-end edge, a side-end edge, and is this the side-end edge with the manufacturer's joint or the opposite side-end edge)? Is this a corner drop, and on which corner? The next consideration is the drop angle concerned. In a rectangular box, are the impacting faces of an edge at a 45-degree angle, or is the center of gravity on a vertical plane radiating from the impact edge? If the drop is a corner drop, is this performed so that the faces adjoining this corner are at equal angles to the impacted surface, or such that a vertical line from the impacted corner passes through the center of gravity?

Does the drop requirement mean two drops on a single box, and are they both on the same edge or corner, or does it mean that two boxes should be tested? If one box is to be tested by two drops, how many samples are required to replicate the results? The answers to these questions are bound to significantly change the results, particularly if the box is a marginal pass-fail.

In the second example, for liquid organic peroxide in a 15 mil plastic bottle inside a special 12B box, only the drop height is stated. This means that any package that can pass any drop from a height of four feet is acceptable. How flat do these flat drops have to be?

There are accepted laboratory test standards which address these problems, but there is no specific regulation for these problems. Finally, no pretest conditioning is specified for fiberboard in any of the current regulation test requirements until January 1, 1991. In addition, the moisture of the fiberboard can affect the performance of a box when subjected to atmospheric conditions, especially stacking strength.

These are only two examples from the existing regulations which illustrate the problems of performing tests in a repeatable and reproducible manner. Similar problems exist in the drop testing of most other packaging. At least this lack of precision in describing test requirements in CFR 49 has been somewhat offset by detailed material and assembly requirements. Under the UN Recommendations, there are no material and assembly requirements. This is good only for new and innovative package designs. On the other hand, with the UN Recommendations, there is still no guarantee that a package which passes will be capable of withstanding the distribution environment. The vague description of test requirements that appear in the UN Recommendations are carried over into HM-181. In the UN forum, such vague test descriptions have at least some small justification. They permit the various national competent authorities to adopt their own detailed testing methods. This permissiveness is bound to lead to some lack of uniformity. The UN could have at least adopted the package testing standards prepared by the International Organization for Standardization (ISO).

In the preparation-for-test section for non-bulk packages, HM-181 required that inner and single packages be filled to not less than 95 percent of their capacity for solids, and not less than 98 percent for liquids, and then drop tested and stack tested. But it fails to state whether these percentages are of the rated or overflow capacity. This can make a significant difference,especially for packaging containing liquids. HM-181 does specify preconditioning for fiberboard packages. However, it does not specify whether this conditioning is performed when wet or dry. Because of hysteresis effects, the result will differ depending on whether the fiberboard had a higher or lower humidity prior to conditioning. While this is a small difference, it may just be the difference between a pass and a fail result (Leblance,1990).

For drop test requirements of drums and other cylindrical packaging, the first drop must be diagonally on a chime, or if the package has no chime, on a circumferential seam or edge. In addition to the problem of the undefined diagonal, the impact point on the chime, seam, or edge is not stated, nor is it stated whether the drop is on the top or bottom chime. This is extremely significant for drums with removable heads which typically use bolt ring closures. If the drop is on the top, is the impact on the bolt area, or offset sufficiently that the bolt area is in the area of maximum deformation near the edge of the crush pattern? If the drum is a tight head design, what is the relation of the point of impact and the welded side seam in steel drums, or the parting line in molded plastic drums? Finally, what is the relation of the fill openings to the impact point? Another series of drums are dropped on the weakest part not tested by the first drop. This might be a closure, or for some cylindrical drums, the welded longitudinal seam of the drum body. To fulfill this requirement adequately, the drum would need to be dropped every conceivable way until the weakest part not previously tested was determined. Owing to the variability of drums, a large number of samples would be required for each of these drops if the results were to have any statistical significance. Without such extensive testing, it is impossible to predict which part is the next weakest. Indeed, the next weakest part might vary from drum type to drum type, or even from drum to drum within a given type. But, the basic information required to select a second drop aspect is not available. This problem introduces variable test results and ensures that results will vary widely, depending on how the test is carried out by a test laboratory (Leblance,1990).

For boxes, four flat drops are required for each package design. They are on top, bottom, long side and short side--one drop per box. For boxes with a manufacturer's joint the requirement fails to specify whether the long side and the short side are those that incorporate the manufacturer's joint, or the opposite side and end. Lastly, there is a corner drop. It is not stated whether this is a diagonal drop. If it is, what is the precise drop angle? The corner to be impacted is not stated, although results will vary widely, depending on the exact means used to perform the tests.

For bags, single-ply bags with side seams must be dropped flat on a wide face, flat on a narrow face and finally on an end. Each of three bags must be subjected to each of the tests, in sequence. It does not state whether bags with a single seam must be dropped on the face containing that seam. For end drops, it does not state whether the end containing a closure valve is to be tested. Multiwall and seamless single-ply bags are dropped flat on a wide face, followed by a drop on an end. Again three bags must be subjected to each of these tests, in sequence. It is not stated whether the end drop is on the valve end (Leblance,1990).

For the design and qualification leakproofness test, and for the hydrostatic test, it is not stated whether testing through the closure is permissible, and if it is, what specific limitations apply. In many cases a test performed through the closure may not be valid. The stacking test does not state permissible load variation limits if a compression tester is used, and whether it should be a fixed head apparatus or have one head swiveled.

Because HM-181 permits self-certification by manufacturers, as well as testing by independent test labs, the possibility for variation in test results is very large. So, ASTM D-4919--Testing of Hazardous Materials Packaging--was published in 1989 under HM-181. Regarding the proposed regulations, it is up to DOT test requirements. They can best do this by referencing D-4919, or they can issue a Competent Authority declaration as detailed in the ASTM standard. If DOT does neither of these, then it would be up to self- certifiers of packaging or independent test labs, to indicate in their test reports that tests were conducted in accordance with the ASTM standard. This allows some measure of protection against litigation that can result from differing interpretations of the regulations (LeBlance,1990).

Those who buy packaging can also protect themselves by requiring that certification testing be carried out in accordance with ASTM standards, and that the supplier certify that this was done. This is important where the buyer's name appears on the package as the manufacturer. This is occurring among suppliers of packaging, particularly with combination packaging, where inner packages are enclosed in an outer shipping package. In this case, the supplier of the outer package, which carries his name as part of the conformance markings, is uneasy. This is because he has no assurance that inner packaging and their assembly are limited to tested types. The solution is to insist that the name of the user appear in the conformance markings (LeBlance,1990).

Furthermore, ASTM D-4169, Performance of Shipping Containers and Systems, is a standard guide of pre-shipment testing. This provides both a uniform basis for evaluating a laboratory, and evaluating the ability of shipping containers to withstand the distribution environment. It explains that this is accomplished by submitting packaging to a test plan consisting of a sequence of anticipated hazardous elements encountered in various distribution cycles. It also states that this practice is not intended to supplant material specifications or existing pre-shipment testing procedures. Finally, it states that the suitability of this practice for use with hazardous materials has not been determined. This latter arises from ASTM reluctance to assume responsibility for safe shipment of hazardous materials. Despite this disclaimer, it is the best available testing regimen to establish that a package can survive the distribution environment, even though not all shipment hazards have been included (Leblance,1990).

However, ASTM D-4169 and UN Recommendations will not absolutely insure that all shipments will withstand the distribution environment. It is prudent to carry out a series of test shipments, with evaluation of packages at the final destination. This is the final assurance that packaging are suitable. It is also useful to inspect the condition of packages at the final destination even though they have performed well in the past.

7.0 SUPER-PAK

(The Solution for a Small Number of UN Combination Packaging)

Super-Pak is outer packaging which has qualified to worst case standards and includes absorbent and leakproof materials. It can be used to ship any inner packaging without testing the assembled combination. The requirements are listed in paragraph 9.7.1.7 of the 7th edition of the UN Orange Book, effective January 1, 1991. Super-Pak provides an alternative for shippers in the non-routine shipping because Super-Pak allows shippers to purchase pre-certified outer packaging without having to test the assembled combination. In addition, the Super-pak provision encourages shippers to follow the rules and declare shipment of dangerous goods. Undeclared shipments of dangerous goods is a safety issue that is receiving attention by the regulatory bodies and the air carrier industry (Hendricks,1990).

The ICAO and IMO set January 1, 1991 as an deadline for converting to UN packaging. The European road and rail modes deadline was May 1, 1990. The change to UN combination packaging will have an impact on shippers. Under DOT rules, the shippers used to purchase certified outer packaging from an outside source. The most common type used is the DOT 12B box. By purchasing a 12B box, the shipper fulfilled his packaging obligation for many chemicals. Conversely, under the UN system, every combination as assembled for transport must meet the UN performance requirements. With the UN rules, a specific combination is defined by size, type, and number of inner packaging being shipped in an outer package. In addition, since the specific gravity and packing group of the material determine the drop height and stacking weight for testing, changes in product can also result in necessary retesting and recertifying for specific combinations. Testing and certifying means the shipper has documented that the combination meets UN Recommendations as stated in Chapter

9 of the Orange Book. Since a shipper generally purchases bottles from one vendor, boxes from a different vendor, and cushioning material from another vendor, it seems inevitable that shippers themselves must be responsible for packaging design and qualification under the UN system. A literal interpretation of the UN requirements would mean further testing or retesting if any changes were made to the type, number, or the configuration of inner packaging in a box. So, the UN amended its ruling to clarify certain minor variations in the form of substitutions of inner packaging that can be made without retesting the combination.

The philosophy behind the Super-Pak is to qualify the outer package under worst case conditions, and to require secondary containment measures in the event the inner packaging leaks. The performance requirements entail:

(a) Performing the drop tests from the Group I drop height, 6 feet, with fragile inner packaging such as glass.

(b) Restricting the use of the package to one half the gross mass of the inner packaging used in the drop test. This use restriction is in essence requiring a "weighted" drop. By doubling the weight allowed in use for the test, you are almost doubling the drop height. This means the shipped package is qualified to withstand a drop from approximately 12 feet.

(c) The stacking test must be performed without any inner packaging in the box. This is a worst case test because inner packaging, such as bottles, often provide structural integrity to a box (Hendricks,1990).

The containment attributes of the packaging are:

(a) If the inner packaging contain liquids, they must be completely surrounded with a quantity of absorbent material sufficient to absorb the entire contents in case of a leak.

(b) The outer packaging must be leakproof if it contains liquids and siftproof if it contains solids. In other words, the outer package must contain an impermeable barrier.

(c) If liquids are transported by air, the outer packaging must be able to withstand the internal pressure tests stipulated by air transport authorities. This internal pressure is a minimum of 14 psi to account for decompression at high altitudes. It may be even higher for higher pressure liquids, in which case the test pressure is determined according to the formulas provided in paragraph 3;1.1.6.1 of the ICAO Technical Instructions (Hendricks,1990).

The UN mark for Super-Pak:

(a) The letters "SP" must appear at the end of the UN mark to indicate that the package was qualified to special standards. This will distinguish it from packages used for solids or combinations tested as assembled for transport.

(b) The mark will also indicate that the package is qualified for Group I materials by an "X" after the first two letters indicating packaging type.

(c) Finally, the one-half the gross mass of inner packaging used in the drop test is the mass used in the marking (Hendricks,1990).

Limited quantity provisions which allow shippers to use non-UN marked packaging could also provide some relief from the testing burden. These provisions are never applicable for Group I materials by any mode of transport. The UN performance standards for combination packaging might pose difficulties for companies that do not have a centralized packaging department, or where occasional shipments must be made from remote locations in a company that does not regularly ship hazardous materials. For example, a company might need to ship a package from a plant at a remote location. Even if a box bearing UN marks for tested combinations were provided, it could be difficult to convey how to configure the combination, including attributes such as the amount and positioning of cushioning material, so that the combination is not significantly different from the tested one. The situation would be even worse if selective testing provisions were applied. However, the person making the shipment would need to:

(a) Ensure that the outer packaging available included the same box and was configured in the same manner as the outer packaging used in the tested combination; and

(b) Compare the inner packaging with packaging used in approved combinations, based on the criteria for allowable substitutions.

In summary, shippers will encounter unique practical problems in switching to UN combination packaging standards. These problems arise from UN 's requirement of testing and certifying combinations as assembled for transport. One effect of the different situation is that the shipper becomes responsible as a package certifier. The responsibility has traditionally rested with the packaging supplier. Another impact of the UN system is a lack of the flexibility needed to address circumstances where the number of shipments of a particular combination is small, or inadequate lead time exists to have a combination tested and certified. Shippers should be aware of the new Super-

Pak category of UN combination packaging, which was adopted to offset some of the practical difficulties encountered with tested combination packages. The new Super-Pak category can be used to ship any inner packaging without testing the pre-certified outer packaging.

8.0 HANDLING EMERGENCIES WITH HAZARDOUS MATERIALS

First, the responder at an accident with hazardous materials will have to recognize nine hazardous material classes; this includes describing the primary dangers of each class of materials. This knowledge will help the responder work correctly to reduce potential harmful consequences. Second, policies and procedures for responding to emergencies should be developed for each site. This plan should describe the following:

(a) All individuals and teams who will participate in an emergency response; their roles, responsibilities, and lines of authority.

(b) A detailed site map showing the locations and types of hazards, site terrain, evacuation routes, refuges, decontamination stations, and off-site populations at risk.

(c) Procedures for communicating on-site (e.g. bullhorns, sirens, hand signals) and offside (e.g. key phone numbers, contact names, two-way radio).

(d) Equipment necessary to rescue and treat victims, to protect response personnel, and to mitigate hazardous conditions on the site.

(e) Medical treatment/first aid techniques.

(f) Emergency response procedures that encompass all phases of response operations, from initial notification through preparation of equipment and personnel for the next emergency.

(g) Procedures for emergency decontamination, including decontaminating the victim(s), protecting medical personnel, and decontamination solutions.

(h) Site security and control measures to ensure that only authorized personnel enter hazardous areas during emergency situations (Cheremisinoff,1989).

Third, the following information can be used to detect the presence of hazardous materials:

(a) Occupancy and/or location of fixed sites and facilities: It could include manufacturing and processing plants, industrial operations, storage facilities, and railroad freight yards.

(b) Container shapes: The configuration of some containers is so unusual that the presence of some hazardous materials can be identified, such as those used for radioactive materials, pressurized products, cryogenics, and corrosives.

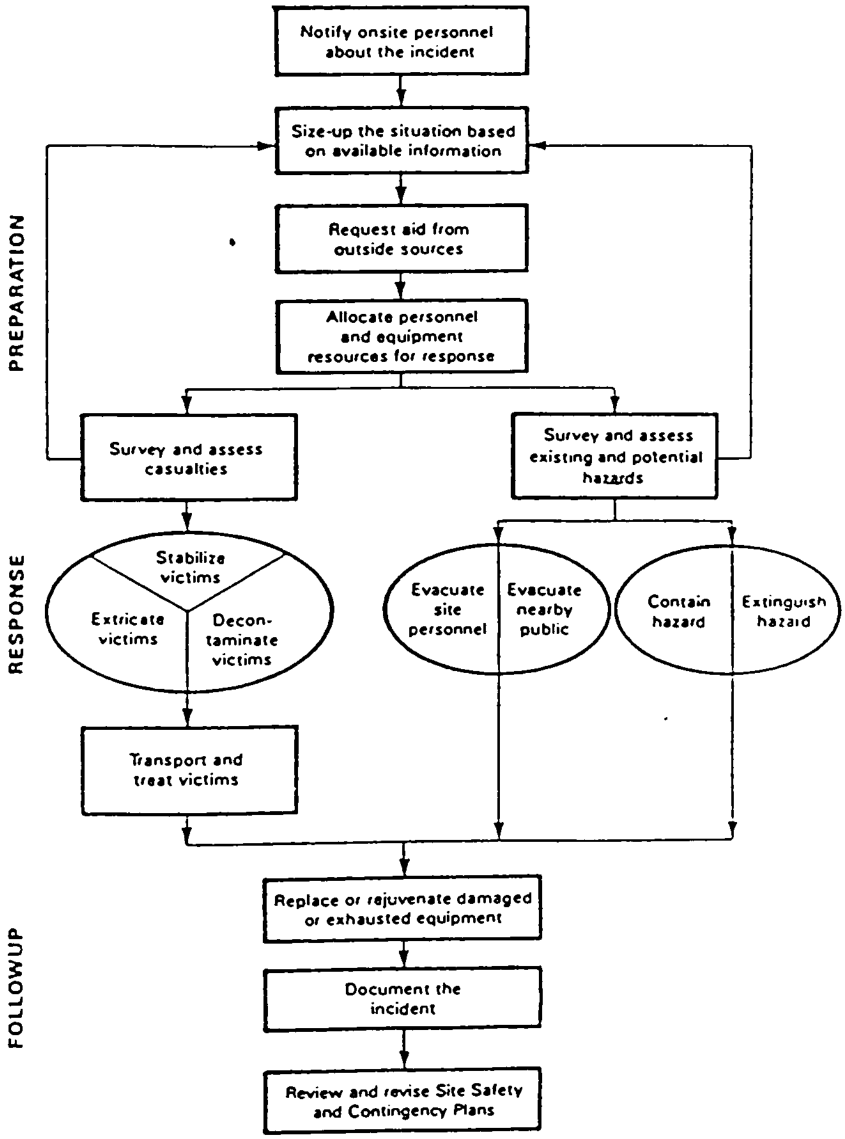
(c) Container markings and colors: This could include the four digit identification number, and military markings. Compressed gas cylinders are color-coded to indicate contents.

(c) Placards and labels: In transportation, the placard would conform to the US Department of Transportation regulations.

(d) Shipping papers and material safety data sheets: Shipping papers would provide information on the shipping name of the product, the identification number, the hazard class, and the quantity. A material safety data sheet provides information on the manufacturer, the hazardous ingredients, physical data, fire and explosion hazard, health and reactivity data, spill procedures, special protection, and special precautions.

(f) Senses: Colors and placards can be seen from a substantial distance, and sight should be used to advantage. All of our senses should be used to assist us in detecting the presence of hazards (Henry,1989).

Table 8 Emergency Response Operations



Source: Paul N. Cheremisinoff. Hazardous Materials Emergency Response. Pennsylvania: Technomic Publishing Company, Inc., 1989, p.56.

Emergency response operations (Table 8) during an actual emergency can be divided into three categories, see table:

(a) Preparation, which involves assessing the situation, allocating personnel and equipment for response, and requesting aid from outside sources.

(b) Response, which involves rescuing, decontaminating, and treating victims, evacuating personnel and/or the public as necessary, and controlling the hazard.

(c) Follow up, which involves replacing equipment, documenting the incident, and reviewing and revising site safety and contingency plans (Cheremisinoff,1989).

In an emergency, crucial messages must be conveyed quickly and accurately. Site staff must be able to communicate information, even through noise and confusion. An internal emergency communication system should be developed, which might consist of a network of radios or field telephones, sirens, whistles, colored flags, and flares. All personnel should be familiar with the procedure for contacting public emergency aid teams such as fire departments, and ambulance units. Furthermore, the team leader must know who is on-site, and must be able to control the entry of site personnel into the hazardous areas to prevent additional injury and exposure. Only necessary rescue and response personnel should be allowed into the exclusion zone. The team leader must also be able to rapidly determine where workers are located and who may be injured (Chermisinoff,1989).

In severe emergency, alternative routes for evacuating victims and endangered personnel should be established in advance, marked, and kept clear. Safe distances for evacuation of personnel or the surrounding community due to the dangers posed by a hazardous substance release can only be determined at the time of an emergency, based on a combination of site and incident-specific factors such as the quantity of substance released, the rate of release, and the wind speed and direction.

Immediately following a hazardous site emergency, the team leader should investigate and document the incident. This documentation is especially important when the incident has resulted in personal injury or property damage to the surrounding environment. Before normal site activities are resumed, government agencies should be notified as required, and personnel must be prepared and equipped to handle another emergency. Equipment should be repaired or restocked. The site safety and contingency plans should be reviewed and revised based on new site conditions and lessons learned from the emergency response (Cheremisinoff,1989).

The emergency command system at hazardous materials emergencies must be structured and procedures for the transfer of command must be clearly indicated. Involvement at the first responder awareness level will usually be minimal and of short duration. The awareness level responder should indicate the need for site control measures to minimize unnecessary contamination and to protect people from the harmful consequences of exposure. The awareness level responder can indicate the need for evacuation by notifying an emergency dispatch center or incoming emergency response personnel. The actions already taken on denial of entry and on isolating the immediate area are the beginning steps in an evacuation process. Other means might be available, depending on circumstances pertaining to the incident, and the variables would be quite numerous. One is limited only by imagination (Henry,1989).

To sum up, hazardous materials emergencies are different from other emergencies because the consequences of exposure to a hazardous material can be far reaching and severe. So, the responder must be specially trained and equipped to perform properly.

8.1 Emergency Phone Numbers

In CFR 49, Part 172.04 states that the person signing the certification in a hazardous material shipment must have direct knowledge that the material offered is properly classified, packaged, marked, labeled, and documented for transportation. This became effective September 17,1990. However, the persons who signs the shipping paper certification must also include an emergency response telephone number:

(a) Entered immediately following the DOT description; or

(b) Entered once on the shipping paper in a clearly visible location if the number applies to all hazardous materials covered by the document; it must indicate that the number is for emergency response.

The telephone number used:

(a) Must be monitored 24 hours per day.

(b) Must be the number of a person possessing, or having immediate access to a person with;

  (i) Knowledge of the dangers and characteristics of the hazardous material being shipped.

  (ii) Comprehensive emergency response and accident mitigation information for the hazardous material.

The telephone number used can be:

(a) The shipper's number; or

(b) Number of an agency or organization capable of providing detailed information concerning the hazardous material such as CHEMTREC.

When the telephone number of the agency is used, the shipper must ensure that prior to transportation of the material the agency has current information on material pertaining to:

(a) Dangers and characteristics;

(b) Comprehensive emergency response and accident mitigation information (Cleveland,1990).

9.0 STATISTICS ON ACCIDENTS

Many countries have some type of system in place to lessen both the chance and severity of hazardous materials accidents. However, problems exist at both the national and international levels in these systems. These problems are characterized by the lack of common standards and practices pertaining to packaging and transporting hazardous materials, inadequacy of reliable accident data collection systems and inadequate enforcement of regulations imposed to govem the transport of hazardous materials.

The common means of commercial transport of hazardous materials include road, railway, water, air and pipeline. It has been reported that about 74 percent of all accidents with dangerous material were related to road transport (Transportation Research Board,1985). Rail accounted for 5 percent and water, 18 percent of accidents. No data are available for air transportation. When the same data were grouped according to quantity of material, water transportation topped the list, accounting for 49 percent of the total of all transportation. Railway and highway transportation followed with 33 percent and 18 percent, respectively. Table 9 summarizes these findings.

Table 9 Transport of Hazardous Materials by Mode

Means of Transport	*Total Accidents with Dangerous Substances (%)*	*Quantity of Substances Involved in Accidents (%)*
Road	74	18
Railway	5	33
Water	18	49
Air	NA	NA
Pipeline	3	NA

Source: Transportation Research Board, Conference on Recent Advances in Hazardous Materials: An International Exchange, Washington, D.C., 1985.

In a 1979 study for the US Senate, hazardous substances were listed in order of frequency of transport (Table 10). The same report listed those hazardous materials involved in the highest percentage of incidents (Table 11).

Table 10 Hazardous Substances by Frequency of Transport

Substance	*% of Shipments*
Gasoline and jet fuels	56
Distillate fuel oil	34
Anhydrous ammonia	4
Paints and allied products	2
Industrial gases (compressed/liquefied)	1
Others	3

Source: Transportation Research Board, *Transportation of Hazardous Materials, Toward a National Strategy,* Vol.1, Special Report, Washington, D.C., 1983.

Table 11 Hazardous Materials by Type

Substance	*Percentage*
Paint and related products	37
Batteries (electric storage, wet)	11
Gasoline	9
Compounds (cleaning, liquid corrosive)	8
Compounds (paint removing, flammable liquid)	7
Other	28

Source: Transportation Research Board, *Transportation of Hazardous Materials, toward a National Strategy,* Vol.1, Special Report, Washington, D.C., 1983.

Furthermore, highway factors that can influence accidents include road conditions, auxiliary lanes, shoulders, medians, roadside conditions, horizontal alignment, vertical alignment, and traffic control. Other factors contributing to accidents are faultily vehicles and the behavior of pedestrians. Tables 12 and 13 present statistics for highway accidents.

Table 12 Road Accidents According to Product Groups

Product Groups	*% of Total Road Accident*
Petroleum	49
Benzene	20
Solvents	7
Toxic Substances	6
Acids and bases	6
Others	12

Sources: Transportation Research Board, Conference on Recent Advances in Hazardous Material: An Intemational Exchange.

Table 13 Road Accidents According to Cause

Cause of Accident	*% of Road Accidents*
Speeding	40
Technical effort	12
Inadequate safety distance	8
Overfatigued	7
Insufficient secured load	7
Various causes	26

Sources: Transportation Research Board, Conference on Recent Advances in Hazardous Materials: An International Exchange.

Table 10 shows that gasoline and other fuels rank top in frequency of transport, accounting for 90 percent of substance shipments. Table 12 is a reflection of Table 10 and shows that petroleum group substances account for nearly 50 percent of road accidents that involve transport of dangerous materials.

For the frequency and severity of accidents, the statistics show that significant accidents related to hazardous materials transportation are only a small portion of all transportation-related accidents. This is due to two main reasons:

(a) Actual accidents are rare. Although some features of the transportation system have considerable influence on accident statistics, the occurrence of accidents is rare and stochastic in nature. In addition, accidents that result in disasters occur rarely, with a low probability in statistical tables.

(b) General care in transporting hazardous materials. Disasters resulting from accidents associated with transportation of hazardous materials are a function of the dangerous properties of the material in transport. People involved in transporting hazardous materials exercise a high level of care as they are usually aware of what they handle. The care usually taken by the people in the transportation business coupled with the inherent low probability of disastrous incidents lessens the frequency of disaster (Transportation Quarterly, 1988).

Unfortunately, infrequent accidents can obscure the fact that conditions of slackened care in the handling, transporting, and storage of dangerous goods could result in an increase of accident frequency and disasters. A statistical problem in the records of disasters associated with hazardous materials in transport is that in many areas of the world only a few such accidents are reported when they occur, and the records of those few are not kept in a form that is helpful for assessment and counter measure planning.

However, the United Nations has played an active role through its various agencies in the production of hazardous materials reference documents and guidelines for dealing with dangerous materials. The U.S. Department of Transportation and the Department of Health keep technical and legislative documents on the proper handling of dangerous materials.

In addition to the United States, other countries with formal establishments for mitigating hazardous materials disasters include: Canada, Czechoslovakia, Denmark, Germany, Finland, France, Hungary, Netherlands, Rumania, and Great Britain. Despite efforts made by these countries in the promotion of safety in this area, table 12 lists some of the major accidents that involved hazardous materials in various countries between 1965-1980 (Transportation quarterly,1988).

Most accidents are caused by small errors, undetected problems, or unforeseen events. Rather than indicative of a lack of necessary care in the circumstances of their occurrence, these accidents demonstrate that even when reasonable care is exercised, there is always a chance that an accident can happen. The disproportion between the slightness of the accident cause and the immense damage that can result is usually what makes an accident something to be feared.

To sum up, statistics indicate that the frequency of accidents resulting from transporting hazardous materials is the highest for road transport. The results of the international mail survey [6] confirmed this observation. Flammable substances and compressed gases are top of the list of common categories of hazardous material. In most countries, there are no designated departments that keep accident statistics on the transport of hazardous materials.

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6 The international survey of hazardous materials transportation was initiated by and carried out under the direction of Dr. Matthew J. Betz, director of the center for advanced Research in Transportation, Arizona State University.

All countries have some kind of disaster response systems but the responsible units are not equipped for handling disasters. Anyway, respondents to the mail survey agreed that there is inadequate control and enforcement of the national and international regulations on safe packaging. That's why, the problems exist on the international level. These problems are defined by the lack of common standards and practices related to packaging and transporting hazardous materials and the inadequacy of reliable accident data collection systems.

10.0 COMPUTER DATA SYSTEMS

The Hazard Assessment Computer System (HACS) is the computerized counterpart of two of the four manuals comprising the U.S. Coast Guard's Chemical Hazards Response Information System (CHRIS): Manual 2, Hazardous Chemical Data; and Manual 3 , Hazard Assessment Handbook. Computer terminal displays can illustrate the relationships for emergency advance planning, and the development and testing of approved hazard assessment methods.

HACS was designed and implemented to answer rapidly and quantitatively the following types of questions:

(a) When will the air/water concentration of a discharged material reach a specific level of toxicity at a given location?

(b) When will the air/water concentration return to a specified safe or nontoxic level?

(c) What is the concentration of discharged material at a specified location and time? (Cashman,1983)

Furthermore, a Hazardous Materials Information System (HMIS) developed by the Department of Defense (DOD), is supplies transportation and safety data to the department's employees and other users who handle, ship, and store hazardous materials. The major goals of the HMIS are:

(a) To locate a central information unit, where data on hazardous materials used by DOD is stored on Materials Safety Data Sheets (MSDS), and to distribute this information to personnel responsible for ensuring proper and safe handling, storage, and use of hazardous materials.

(b) To centrally store and distribute sufficient data to ensure shipment in compliance with the Department of Transportation, the Air Force, the Inter-Governmental Maritime Consultative Organization, and the International Air Transport Association.

(c) To provide data that will assist in the safe disposal of these same hazardous materials.

The procurement officer obtains a Material Safety Data Sheets (MSDS) from the supplier/contractor as part of the procurement process. The officer reviews the data for technical accuracy and conformance with automated data processing program constraints. Also the focal point will prepare a transport data sheet for each hazardous item regulated for shipping. During the data process, data is screened for legibility and edited for conformance to field size and character configuration requirements. In addition to routine entry of new records into the system; corrections and deletetions can also be made. The primary output is a composite microfiche publication of all the data in the system that is produced annually with quarterly cumulative updates. Weekly hardcopy updates are provided to DOD focal points to assist with inquiries between publication cycles (Cashman,1983).

The Oil and Hazardous Materials Technical Assistance Data System (OHMTADS) is available to emergency response personnel by telephone hookup to a computer terminal. OHMTADS stores detailed information on hundreds of chemical compounds. The information has been entered into the computer from the literature on hazardous materials. It emphasizes the effect the materials can have when spilled; further information includes trade names, synonyms, chemical formulas, major procedures, common modes of transportation, flammability, explosiveness, potential for air pollution, methods of analysis, and chemical /physical /biological / toxicological properties. In less than 15 minutes, OHMTADS can relay procedures for safe handling and cleanup of spilled materials. OHMTADS also allows identification of unknown materials. After key characteristics of the unknown materials are entered into the system, OHMTADS screens for candidate substances with similar physical and chemical properties. For example, if the computer is given the color, odor, density, etc. of an unknown material, it will generate a list of candidates. Continued elimination of substances on this list will lead to identification of the material (Cashman,1983).

10.1 Computer Software

The Bureau of Dangerous Goods, Ltd. has developed two software packages, SHIP HAZMAT and HAZMAT, that aid shippers of hazardous materials.

The SHIP HAZMAT program is an automated document and package preparation system designed to assist shippers of dangerous goods in complying with regulations. The advantages of SHIP HAZMAT are as follows:

(a) Computer generated shipper's declaration forms.

(b) Entry-by-entry verified at each step.

(c) Shipper's declaration completed in four part form in accordance with ICAO/IATA and USA regulations.

(d) Diagram showing inner and outer packaging, quantities, marking and labeling requirements.

(e) Allowing company product identification code cross referencing with UN or ID number.

The HAZMAT program is an automated document and package verification system designed to assist freight forwarders and air cargo carriers in verifying the accuracy of the shipper's declarations. The advantages of HAZMAT are as follows:

(a) Application of ICAO/IATA regulations.

(b) Listing of State and Operator Variations.

(c) US Government Variations are automatically applied.

(d) Printed diagram of documentation.

(e) Definition of package requirements in Graphics (Bureau of dangerous goods, Ltd.,1990).

Moreover, the UN/ID number triggers the classification, packaging, marking, labeling, documentation, degree of risk, and emergency response guidelines. Equipment control, computer pricing, and automatic invoice generation are software packages that can be combined with hazardous materials documentation and even the material safety data sheet. Computer software for this specific use is bound to grow in the 1990.

APPENDIX

APPENDIX A

LIST OF ACRONYMS AND OTHER REFERENCES

49 CFR	-	transportation section of the Code of Federal Regulations
ADR	-	European Agreement Concerning the International Carriage of Dangerous Goods by Road.
ASTM	-	The American Society for Testing Materials
ATA	-	Air Transport Association
ATA	-	American Trucking Associations, Inc.
AUI	-	Associated Universities, Inc.
BAM	-	West Germany's Bundeanstatlt Fur Material Prufung
BEA	-	Bureau of Economic Analysis Region (U.S. Department of Commerce)
BEA Region	-	Bureau of Economic Analysis Region (U.S. Department of Commerce)
BMCS	-	Bureau of Motor Carrier Safety
CAER	-	Community Awareness and Emergency Response
CERCLA	-	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	-	Code of Federal Regulations
CHEMTREC	-	Chemical Transportation Emergency Center
CHRIS		Chemical Hazards Response Information system
CMA	-	Chemical Manufacturers Association

CPI	-	Consumer Price Index
CTC		Canadian Transport Commission
CTS	-	Commodity Transportation Survey (US Bureau of the Census)
DMV	-	Division of Motor Vehicles
DOD	-	US Department of Defense
DOE	-	US Department of Energy
DOT	-	US Department of Transportation
ECE	-	Economic Commission for Europe
ECOSOC	-	Economic and Social Council
ENC	-	East North Central
EODA	-	Explosive and Other Dangerous Articles Act
EPA	-	US Environmental Protection Agency
ESC	-	East South Central
FAA	-	Federal Aviation Administration
FCS	-	Freight Carload Statistics (ICC)
FEMA	-	Federal Emergency Management Agency
FHWA	-	Federal Highway Administration
GAO	-	US General Accounting Office
GVWR	-	gross vehicle weight ratings
HACS	-	The Hazard Assessment Computer System
HMIR	-	Hazardous Materials Incident Reports
HMIS/HMTA	-	Hazardous Materials Transportation Act
IACP	-	International Association of Chiefs of Police
IAEA	-	International Atomic Energy Agency
IATA	-	International Air Transport Association
ICAO		International Civil Aviation Organization

ICC	-	Interstate Commerce Commission
IMCO	-	Intergovernmental Maritime Dangerous Goods
IMDG	-	International Maritime Dangerous Goods
IMO	-	International Maritime Organization
MTB	-	Materials Transportation Board
MTU		metric tons uranium
MSDS		Materials Safety Data Sheets
NEPA	-	National Environmental Policy Act
NFPA	-	National Fire Protection Association
NHTSA	-	National Highway Transportation Safety Administration
n.o.s.	-	not otherwise specified
NPRM	-	Notice of Proposed Rulemaking
NRC	-	National Response Center (US Coast Guard)
NRT	-	National Response Team
NTSB	-	National Transport Safety Board
OHMT	-	Office of Hazardous Materials Transportation
OHMTADS	-	Oil and Hazardous Materials Technical Assisitance Data Syatem
ORM	-	Other Regulated Materials
OSHA	-	Occupational Safety and Health Administration
OTA		Office of Technology Assessment
PATRAM	-	Packaging and Transportation of Radioactive Materials
PPE	-	personal protective equipment
psi	-	pounds per squareinch

PWR	-	pressurized water reactor
RID	-	Regalements International Dangerous Goods
RQ	-	reportable quantity
SARA	-	Superfund Amendments and Reauthorization Act
SHMED	-	State Hazardous Materials Enforcement Development program
SIC	-	Standard Industrial Classification
StAA	-	Surface Transportation Assistance Act
STCC	-	Standard Transportation Commodity Code (ICC)
TDG	-	Transportation of Dangerous Goods Regulations
TNO	-	The Dutch Netherlands Packaging Research Institute
TSC	-	Transportation System Center
TSCA	-	Toxic Substances Control Act
TSI	-	Transportation Safety Institute
TSUSA	-	Tariff Schedule for United States Annotated
UFC	-	Uniform Freight Classification
UN/NA	-	United Nations/North American hazardous materials code
UNK	-	region unknown
UP	-	Union Pacific
U.S.C.	-	United States Code
USCG	-	US Coast Guard

APPENDIX B

HAZARDOUS MATERIALS DEFINITIONS

Hazardous Materials --DOT uses this term which covers eight hazard classes, some of which have subcategories called classifications, and the ninth class covering other regulated materials (ORM). DOT includes in its regulations hazardous substances and hazardous wasted as an ORM-E, both of which are regulated by the Environment Protection Agency (EPA), if their inherent properties would not otherwise be covered.

Hazardous Substances--EPA uses this term for the chemicals which, if released into the environment a certain amount, must be reported and, depending on the threat to the environment, federal involvement in handling the incident can be authorized. A list of the hazardous substances is Published in 40 CFR Part 302, Table 302.4.

Extremely hazardous Substances--EPA uses this term for the chemicals which must be reported to the appropriate authorities if released above the threshold reporting quantity. Each substance has a threshold reporting quantity. The list of extremely hazardous substances is identified in Title III of Superfund Amendments and Reauthorization Act (SARA) of 1986 (CFR 40 Part 355).

Toxic Chemicals--EPA uses this term for chemical whose total emissions or releases must be reported annually by owners and operations of certain facilities that manufacture, process, or otherwise use a listed toxic chemical. the list of toxic chemicals is identified in Title III of SARA.

Hazardous Wastes --EPA uses this term for chemicals that are regulated under the resource, Conservation and Recovery Act (CFR 40 Part 261.33). Hazardous wastes in transportation are regulated by DOT (CFR 49 Parts 170-179).

Hazardous Chemicals--The United States Occupational and Health Administration (OSHA) uses this term to denote any chemical that would be a risk to employees if exposed in the work place. Hazardous chemicals cover a broader group of chemicals than the other chemical lists.

Radioactive Materials --A radioactive material is defined as any substance with a specific activity grater than 0.002 microcurie per gram.

Corrosive Materials --These are substances that, by chemical action, will cause severe damage when in contact with living tissue, or, in the case of leakage, will materially damage or even destroy other freight or the means of transport; they may also cause other hazards.

Other Regulated Materials --These are substances that during transport present a danger not covered by other classes, but posses enough hazardous characteristics in transport that they require some regulation.

ORM A --is a material that has an anesthetic, irritating, noxious, toxic, or other similar property and that can cause extreme annoyance or discomfort to passengers and crew in the event of leakage.

ORM B --is a material capable of causing significant damage to a transport vehicle or vessel from leakage during transportation; an example would be quicklime.

ORM C--is a material that is unsuitable for shipment unless properly identified and prepared for transportation. An example would be excelsior.

ORM D--is a material, such as a consumer commodity, that meets the definition of a hazardous material but presents a limited hazard during transportation because of its form, quantity, and packaging. An example would be household cleaning supplies.

ORM E-- is a material that is not included in any other hazard class but is subject to the requirements of this subchapter. Materials in this class include hazardous waste and hazardous substances as defined by DOT and EPA regulations. An example would be waste acetone.

Air reactivity -- reactivity deals with the characteristic of a substance to experience a release of energy or to undergo change. Some materials are self-reactive or can polymerize. Others undergo violent reaction if they contact other materials. Air reactivity describes substances that will ignite or release energy when exposed to air.

Catalysts and inhabitors -- a catalyst is a substance that affects the rate of a chemical reaction without being changed itself by the reaction. Catalysts are usually employed to increase the speed of chemical reaction.

An inhibitor is a substance that is used to retard the rate of a chemical reaction. Inhibitors are often added to materials that tend to be self-reactive in order to make those materials more stable.

Concentration -- is a term used to indicate the amount of an active ingredient that is contained in a given solution. Concentrations can be expressed in percent by weight or percent by volume.

Corrosivity --is a measure or tendency of a substance to deteriorate in the presence of another substance or in a particular environment. As an example, steel tanks installed below ground are subject to corrosion. The soil in which they are placed can be measured for corrosivity, and measures can be taken to protect the tank.

Critical temperature and pressure --critical temperature is the minimum temperature above which a gas cannot be liquefied no matter how much pressure is applied. The critical pressure describe the pressure that must be applied to bring a gas to the liquid state at its critical temperature. A gas cannot be liquefied at a temperature above its critical temperature. It can be liquefied at a temperature below its critical temperature. The lower the temperature, the less the pressure required to bring it to the liquid state.

Instability--is used interchangeably with reactivity. It speaks to the susceptibility of a material to release energy by itself or in combination with other materials.

Oxidation ability--is a measure of a substance's propensity to yield oxygen. Most oxidizers contain large amounts of chemically bound oxygen. The oxygen is easily released, especially when heated, and it will accelerate the burning of combustible materials.

pH-- the pH of a substance is a numerical measure of its relative acidity or alkalinity. A neutral level is expressed as pH of 7.0. Designations above that level indicate increasing alkalinity, and designations below indicate increasing acidity. The pH is the accurate determine of the hydrogen ion concentration of a solution.

Polymerization --describes what is often a violent reaction, involving the process of forming a compound from several single molecules of the same substance. Polymers are compounds whose large molecules are formed by the repetitious union of many small molecules.

Radioactivity --describes the spontaneous emission of particles or rays from substances that are called radioactive elements.

Self-accelerating decomposition temperature (SADT) --is the temperature above which the decomposition of an unstable substance continues unimpeded, regardless of the ambient or external temperature.

Strength --is a term used to described the concentration of a solution.

Sublimation --is the passing of a substance directly from the solid state to the vapor state, without passing through the liquid state. Solids such as naphthalene (moth balls) are an example. The opposite of sublimation is known as deposition. An increase in temperature increases the rate of sublimation.

Surface tension --describes the attractive force between the surface molecules of a liquid. The surface tension of a substance will determine the ability of a liquid to spread on a surface.

Viscosity--is a measure of the thickness of a liquid and will determine its ease to flow. Liquids with high viscosity, such as heavy oils, have to be heated to increase their fluidity.

Volatility--describes the ease with which a liquid or solid can pass into the vapor state. The higher the volatility, the greater the rate of evaporation. Vapor pressure is a measure of a liquid's propensity to evaporate. The higher the vapor pressure, the more volatile the liquid.

Water reactivity--describes the sensitivity of materials to water, without requiring heat or confinement. Some materials are capable of reacting explosively on exposure to water.

Combination Packaing--are a cambination of packagings for transportation purposes, consisting of one or more inner packagings secured in an outer packaging.

Packaging Design Type --is defined by the design, size, material, and thickness, manner of construction, and packaging, but may include various surface treatments.

Source: Martin F. Henry. Hazardous Materials Response Handbook. Massachusetts: National Fire Protection Association,1989, pp.12-14, pp. 80-83.

APPENDIX C

LIST AND DESCRIBE THE NINE HAZARDOUS MATERIALS, AND GIVE EXAMPLE OF EACH CLASS

Class	Hazards	Examples
1. Explosives	Primary purpose is to function by explosion; overpressure or shock wave; fires; fragmentation	dynamite, TNT, display fireworks
2. Gases	Under considerable pressure at normal temperature; may be flammable or corrosive	propane, chlorine, oxygen
3. Flammable Liquids	Ability to burn	gasoline, toluene
4. Flammable Solids	Ignites readily and burns vigorously	white phosphorus, metallic sodium
5. Oxidizers and Organic Peroxides	Readily releases oxygen, stimulates burning	sodium chlorite, nitric acid, sodium nitrate, benzoyl peroxide
6. Poisonous and Etiologic Materials	High degree of heath hazard; disease causing	hydrogen cyanide, tetraethyl lead, rabies virus

7. Radioactive Materials	Radioactive exposure; contamination; radiation poisoning	enriched uranium, plutonium, radioactive waste
8. Corrosive Materials	Can destroy human tissue; some are oxidizers; some are toxic or unstable	sulfuric acid, sodium hydroxide
9. Other Regulated Materials (ORMs)	Possess hazardous characteristics in transport	Chloroform, household cleaners

Sources: Martin F. Henry, Hazardous Materials response Handbook. Massachusetts: Natinal Fire Protection Association,1989, p.41

APPENDIX D

ABBREVIATION AND UNIT SYMBOLS

Property	*English Units*	*Metric Units*
length	in	cm
mass	lb	kg, g
volume	mL	cm^3
power density	pound-force per sq in	kPa (kilopascal)
	pound-force per sq ft	kPa
temperature	°F	°C
pressure	lb/in^2	kg/cm^2
density	lb/ft^3	g/cm^3
tensile strength	lb/in^2	kg/cm^2

CONVERSION FACTORS TO "ENGLISH" UNITS

To convert from	*To*	*Multiply by*
centimeters	feet	3.281×10^{-2}
centimeters	inches	0.3937
centimeters	meters	0.01
centimeter-grams	meter-kgs	10^{-5}
centimeter-grams	pound-feet	7.233×10^{-5}
centimeters / sec	feet / min	1.1969
centimeters / sec	feet / sec	0.03281
centimeters / sec / sec	feet / sec / sec	0.03281
centimeters / sec / sec	kms /hr /sec	0.036
cubic centimeters	cu feet	3.531×10^{-3}
cubic centimeters	cu inches	0.06102
cubic centimeters	cu meters	10^{-6}
cubic centimeters	gallons	2.642×10^{-4}
cubic centimeters	liters	0.001
cubic feet	cu cms	28,320.0
cubic feet	cu inches	1,728.0
cubic feet	gallons	7.48052
cubic feet	liters	28.32
cubic feet / min	gallons / sec	0.1247
cubic feet / sec	gallons / min	448.831
cubic inches	gallons	4.329×10^{-2}
cubic inches	liters	0.01639
feet	centimeters	30.48
gallons	cu cms	3,785.0

gallons	cu feet	0.1337
gallons	cu inches	231.0
gallons	liters	3.785
gallons / min	cu ft / sec	2.228×10^{-3}
gallons / min	liters / sec	0.06308
gallons / min	cu ft / hr	8.0208
inches	centimeters	2.540
kilograms	pounds	2.205
kilograms / sq meter	pounds / sq ft	0.0248
kilograms / sq meter	pounds / sq in	1.422×10^{-2}
kilopascal	pound-force / sq ft	20.8854
kilopascal	pound-force / sq in	0.1450377
liters	cu cm	1,000.0
liters	cu feet	0.03581
liters	cu inches	61.02
liters / min	cu ft / sec	5.886×10^{-4}
liters / min	gals / sec	4.403×10^{-2}
meters	centimeters	100.0
meters	feet	3.281
meters	inches	39.37
meters	kilometers	0.001
meters / min	feet / min	3.281
meters / min	feet / sec	0.05468
meters / min	kms / hr	0.06
meters / sec	feet / min	196.8
meters / sec	feet / sec	3.281
pounds	kilograms	0.4536

pounds	ounces	16.0
pounds of water	cu feet	0.01602
pounds of water	cu inches	27.68
pounds of water	gallons	0.1198
pounds of water / min	cu feet / sec	2.670×10^{-4}
pounds / cu ft	grams / cu cm	0.01602
pounds / cu ft	kgs / cu meter	16.02
pounds / cu ft	pounds / cu in	5.787×10^{-4}
pounds / cu in	gms / cu cm	27.68
pounds / cu in	kgs / cu meter	2.768×10^{4}
pounds / cu in	pounds / cu ft	1,728.0
pounds /in	gms / cm	178.6
temperature (°C) + 273	absolute temperature (°C)	1.0
temperature (°C) + 17.78	temperature (°F)	1.8
temperature (°F) + 460	absolute temperature (°F)	1.0
temperature (°F) - 32	temperature (°C)	5/9

LIST OF REFERENCE

Anonymous. Transport Research Board, Transportation of Hazardous Materials, Towards a National Strategy (vol.1), Washington, D.C., 1983.

Anonymous. Transport Research Board, Conference on Recent Advances in hazardous Materials: An International Exchange. Washington, D.C., 1985.

Anonymous. ASTM, second edition. Philadelphia, 1987.

Anonymous. The Title 49 of the Code of Federal Regulations. Illinois: Label master, 1988.

Anonymous. Transportation quarterly, vol.42, no.1, January 1988, p.125-139. Connecticut: Eno Foundation for Transportation, Inc., 1988.

Anonymous. Air Waybill Handbook, 12th edition. Illinois: Label master, 1989.

Anonymous. Recommendations on the Transport of dangerous goods, second edition. Illinois: Label master, 1990.

Anonymous. Dangerous Goods Regulations, 31st edition. Illinois: Label master, 1990.

Anonymous. International Civil Aviation Organization, 1989-1990 edition. Illinois: Label master, 1990.

Altemos, Andy. "Selecting Testing of Combination Packaging." From The Chemical Packaging Review, volume 1, number 2, p. 7, Jul-Aug, 1990.

Altemos, Andy. "HM-181: Performance-Oriented Packaging Standards." From The Chemical Packaging Review, volume 2, number 3, p. 14-16, Sep-Oct, 1991.

Bierlein, Lawrence W. Red Book on Transportation of Hazardous Materials, second edition. New York: Van nostrand reinhold company, 1987.

Bierlein, Lawrence W. What To Do When The DOT Hazardous Materials Inspector Calls. Illinois: Label master, 1989.

Bierlein, Lawrence W. "Regulation of Emptied Hazardous Materials Packaging." From The Packaging Chemical Review, volume 1, number 4, p.9, Nov-Dec, 1990.

Cashman, John R. Hazardous Materials Emergencies Response and Control. Pennsylvania: Technomic Publishing Co., Inc., 1983.

Cheremisinoff, Paul N. Hazardous Materials Emergency Response. Pennsylvania: Technomic Publishing Company, Inc., 1989.

Cleveland, Joseph. "Emergency Response Communication Standards." From The Chemical Packaging Review, volume 1, number 1, p. 11, May-Jun, 1990.

Dull, Larry . "HM-181: The Advantages of Performance Testing." From The Chemical Packaging Review, volume 1, number 2, p. 28, Jul-Aug, 1990.

Earl, G.F. Fibre Box Handbook. Illinois: Fibre Box association, 1987.

Elkin, Samuel S. "Effects of HM-181 on Internatinoal Air Regulations." From The Chemical Packaging Review, volume 2, number 2, p. 17-18, Jul-Aug, 1991.

Hendricks, Lynnette. "Super-Pak." From The Packaging Chemical Review, volume 1, number 4, p.25, Nov-Dec, 1990.

Henry, Martin F. Hazardous Materials Response Handbook, first edition. Massachusetts: National Fire Protection Association, 1989.

Herodes, Annamarie. "HM-181: Classifications." From The Packaging Chemical Review, volume 2, number 2, p.13-15, May-Jun, 1991.

Keller, J.J. and associates. Hazardous Materials Shipment, Classification, Identification and Procedures for Shippers of Hazardous Materials. J.J. Keller and Associates, Inc., 1977.

LeBlance, J.J. "Hazardous Materials Packaging in ASTM Standardization News." November, 1989, p. 30-32.

Leblance, John J. "Testing Problems with Hazardous Materials." From The Chemical Packaging Review, volume 1, number 4, p. 17, Nov-Dec, 1990.

Leblance, John J. "Testing Problems with Hazardous Materials." From The Chemical Packaging Review, volume 1, number 3, p. 26, Sep-Oct, 1990.

LeBlance, J.J. "Testing Problems with Hazardous Materials Packages." From The Chemical Packaging Review, volume 1, number 3, p. 27, Sep-Oct, 1990.

Mostyn, Harry. Packaging Dangerous Goods for Transport, 1986 edition. England: Aurigny Limited, 1986.

Nelson, W. Accelerated Testing. John Wiley & Sons, 1990.

Prothero, T.G. "Empty Container Disposal." From The Chemical Packaging Review, volume 1, number 4, p. 11, Nov-Dec, 1990.

Raymus, Jack. "Packaging Opportunities Looking Beyond HM-181." From The Chemical Packaging Review, volume 1, number 1, p. 12, May-Jun, 1990.

Richard, Robert A. "A Discussion Concerning DOD's Plans and Actions." From The Chemical Packaging Review, volume 1, number 4, p.20, Nov-Dec, 1990.

Rousseau, Gordon "HM-181: Performance Packaging Standards." From The Chemical Packaging Review, volume 2, number 3, p.17-18, Sep-Oct, 1991.

Ten Eyck, Robert. "Sequential testing." From The Chemical Packaging Review, volume 1, number 1, p.4-5, May -Jun, 1990.

Ten Eyck, Robert. "A Review of ASTM Procedure." From The Chemical Packaging Review, volume 1, number 3, p.12, Sep-Oct, 1990.