



U.S. Department of Transportation
Research and Special Programs
Administration

RADIOACTIVE MATERIAL REGULATIONS REVIEW



RAMREG -001-98

TO THE READER:

This review provides guidance on the DOT Hazardous Materials Regulations contained in Title 49, Code of Federal Regulations (HMR; 49 CFR) which govern the packaging and shipment of radioactive material. These materials have an excellent safety record when packaged, labeled, marked and transported in accordance with these regulations.

Hazardous materials (hazmat) employers are required to ensure that each hazmat employee is trained in accordance with the requirements prescribed in 49 CFR 172.702. The HMR requires “hazmat employers” involved in the transport of radioactive material, e.g., shippers and carriers, to properly train their “hazmat employees”. The present document is designed to assist in advanced-level training of hazmat employees who are involved with radioactive material packaging and transportation.

This review, as a reference document, is not an official interpretation or restatement of the regulations. This document may be reproduced without further permission from DOT, subject to the following.

The name and the seal of the U.S. Department of Transportation may not be reproduced unless that copy accurately reproduces the entire content (text, and format) of this document without modification. In addition, the publisher’s full name and address must be displayed on the cover of each copy.

Comments, suggestions, corrections or requests for additional training aids should be mailed to: U.S. Department of Transportation, Office of Hazardous Materials Initiatives and Training, DHM-50, 400 Seventh Street, SW, Washington, DC, 20590-0001.

NOTE: This document should not be used by itself. This review of the radioactive material regulations was designed as a guidance document and should not be used without simultaneous reference to all applicable and current regulations pertaining to the transportation of radioactive material. Users of this review are strongly encouraged to obtain from the Government Printing Office the latest copy of the HMR⁵. Amendments to the regulations are published in the Federal Register.

TABLE OF CONTENTS

I.	BACKGROUND DISCUSSION.....	1
A.	General.....	1
B.	Historical.....	2
II.	REGULATORY SOURCES AND ORGANIZATIONS.....	3
A.	Organizations.....	3
B.	Federal Regulations.....	4
C.	International Regulations.....	5
D.	Other Domestic Sources of Regulations and Tariffs.....	6
III.	THE A₁/A₂ SYSTEM OF LIMITING PACKAGE ACTIVITY.....	7
A.	Definition of Radioactive Material For Purposes of the Transportation Regulations.....	7
B.	SI and Customary Radiological Units.....	8
C.	A Good Approach to Determining Activity Limits of Packages.....	8
D.	A ₁ and A ₂ Quantity Limits and Packaging.....	9
E.	Special Form Radioactive Materials (A ₁).....	10
F.	Normal Form Radioactive Materials (A ₂).....	13
G.	Highway Route Controlled Quantities (HRCQ).....	13
H.	The A ₁ /A ₂ Spectrum of Package Activity Limitation.....	15
IV.	RADIATION AND CONTAMINATION LIMITS.....	15
A.	Package Radiation Limits.....	15
B.	Definition of the Transport Index (TI).....	17
C.	Exclusive-use Shipment Radiation Limits.....	17
D.	Contamination Limits and Contamination Surveys.....	21
V.	CATEGORIES OF RADIOACTIVE MATERIALS PACKAGES.....	22
A.	Basic Principle of Radioactive Materials Packaging.....	22
B.	General Packaging Requirements.....	23
C.	Categories of Excepted Packages.....	24
D.	Type A Packages.....	26
E.	Type B Packages.....	30
1.	Package Test Standards.....	30
2.	Authorized Type B Packages.....	34
3.	Foreign-made Type B Packages.....	34
F.	Industrial Packages (IP-1, IP-2, IP-3).....	35
G.	Fissile Radioactive Material Packages and Shipments.....	35

VI. LOW SPECIFIC ACTIVITY (LSA) AND SURFACE CONTAMINATED OBJECTS (SCO) SHIPMENTS.....	39
A. Background.....	39
B. Definition of LSA.....	39
C. Definition of SCO.....	40
D. Radiation Level Limit for Unshielded LSA/SCO Materials.....	41
E. Authorized LSA/SCO Packaging.....	42
F. Conveyance Activity Limits For LSA/SCO.....	46
VII. 49 CFR 172 HAZMAT COMMUNICATIONS AND RELATED REQUIREMENTS.....	46
A. General.....	46
B. 172.101 List of Hazardous Materials and Proper Shipping Names for Radioactive Materials (Subpart A & B).....	47
C. Shipping Paper Requirements (Subpart C).....	48
D. Marking Requirements (Subpart D).....	54
E. Labeling Requirements (Subpart E).....	55
F. Placarding Requirements (Subpart F).....	57
G. Emergency Response Information Requirements (Subpart G).....	58
H. Training Requirements (Subpart H).....	60
VIII. OVERVIEW OF NRC'S 10 CFR TRANSPORT-RELATED REQUIREMENTS.....	61
A. 10 CFR PART 71.....	61
B. 10 CFR PART 20.....	62
C. 10 CFR PART 61.....	63
IX. OTHER REQUIREMENTS.....	63
A. Types of Carriers and Carrier Requirements.....	63
B. Registration Requirements.....	64
C. Motor Carrier Safety Requirements.....	65
D. Quality Assurance/Quality Control Requirements.....	66
E. Shipment of Uranium Hexafluoride (UF ₆).....	66
F. DOT and NRC Enforcement Policies.....	67
X. IAEA REGULATIONS.....	68
XI. LISTS OF REFERENCES.....	69
APPENDIX A – Nomenclature and SI Units.....	76

TABLES AND FIGURES

TABLES		PAGE
1	Sources of Federal Regulations.....	5
2	Availability of International Regulations.....	6
3	Other Domestic Sources of Regulations and Tariffs.....	7
4	Type A Package Quantity Limits for Selected Radionuclides.....	10
5	Radiation Limits-Packages In Non-Exclusive Use Conveyances and Package Stowage Restrictions.....	16
6	Transport Index Limits for Freight Containers and Conveyances Aboard Vessels.....	20
7	Non-fixed External Surface Contamination Wipe Limits.....	21
8	Activity Limits for Excepted Packages.....	25
9	Contamination Limits for SCO's.....	41
10	Industrial Package Types Required for LSA and SCO shipments.....	43
11	Conveyance Activity Limits for LSA/SCO.....	46
12	Most Commonly Used Proper Shipping Names for Radioactive Material.....	48
13	Less Frequently Encountered Proper Shipping Names by Chemical Name- Materials Having a Subsidiary Hazard.....	48
14	Label Category Based on TI and Surface Radiation Level.....	57

FIGURES		PAGE
1	NRC Agreement States as of 1997.....	4
2	Special Form Radioactive Material.....	11
3	Normal Form Radioactive Material.....	13
4	The Transport Activity Spectrum.....	15
5	Limits On Package Radiation Levels.....	16
6	Radiation Level and TI limits for Non-Exclusive Use Open or Closed Transport Vehicles.....	17
7	Radiation Level Limits-Conventional Closed Exclusive-Use Transport Vehicles.....	18
8	Radiation Level Limits-Open (Flatbed) Exclusive-Use Transport Vehicles – <u>Without</u> Access - Limiting Enclosure.....	19
9	Radiation Level Limits-Open (Flatbed) Exclusive-Use Transport Vehicle – <u>With</u> Access-Limiting Enclosure.....	19
10	The Transport Activity Spectrum (With Packaging References).....	23
11	Typical Type A Package Configurations.....	28
12	Typical Type B Package Configurations.....	32
13	Fissile Radioactive Materials Packaging.....	36
14	Typical Packages for Radioactive Waste.....	44
15	Package Labels.....	56
16	Vehicle Placard.....	58

I. BACKGROUND

A. GENERAL

Since the beginning of the atomic energy industry over 50 years ago, there has been an excellent record of safety in the transportation of nuclear materials. It is estimated that over four million packages containing radioactive material are transported in commerce annually within the U.S.

To date, there have been no known deaths or serious injuries to transport workers, emergency services personnel, or the general public as a result of the radioactive nature of the material. This safety record can be attributed to the proper packaging of radioactive material and the effectiveness of the transportation safety standards and regulations.

Notwithstanding this excellent record of safety, negative perceptions about radiation and radioactivity continue to persist in the minds of many persons, sometimes even giving rise to a lack of confidence in the existing safety standards. Words such as "radioactive", "radioactivity", "atomic", "nuclear wastes", etc., generate concern and fear in the minds of many persons. The atomic bomb, nuclear power plant accidents, and exaggerated hazards of cleanup at former nuclear weapons facilities have also created uneasiness in the minds of the public. Consequently, hundreds of state and local laws have been enacted in recent years in attempts to control or ban the transportation of radioactive wastes, spent nuclear fuel, and at times all radioactive material. It is in the spirit of easing and addressing these fears through education, that this review was developed. This review provides the reader with information for use in advanced-level radioactive material transportation training.

Modern society uses radioactive material to generate electric power, and for research, manufacturing, and a wide range of industrial processes. In addition, these materials are indispensable for medical diagnosis or therapy. These materials and any waste products are regularly transported in commerce. Many medical materials of very short "half-life" must be transported from the producer to the point of use by the most rapid means of transportation, utilizing both aircraft and motor vehicle.

Industrial applications of radioactive material include inspection and "gauging" operations such as examining the integrity of welded joints or measuring the thickness of paper as it is produced. Sealed radioactive sources are also used extensively in oil and gas exploration drilling operations and to check the compactness of roadbeds during paving operations. Each year there are new applications of nuclear technology. DOT updates the transport regulations periodically to keep pace with the changing transportation scene, and maintain consistency with the changing international standards. These changes are also aimed at maintaining and upgrading the existing excellent safety record.

B. HISTORICAL

In the early 1950's, the Interstate Commerce Commission (ICC) first established radioactive material regulations limiting the radiation levels that emanate from packages to protect radiation-sensitive cargo, e.g., photographic film, which might be transported with radioactive material packages. By protecting such radiation-sensitive cargo, protection was also provided to the drivers and passengers.

In 1961, the International Atomic Energy Agency (IAEA) adopted radioactive material transportation regulations (standards) based largely on those of the ICC. These IAEA regulations became the first international radioactive material regulations. IAEA recommended that member states and international transport organizations adopt the IAEA regulations as a basis or standard for their own domestic national requirements.

In 1967, IAEA Safety Series No. 6 (SS6) was substantially revised. This revision included a new category of materials - **large radioactive sources**. This category was considered special because of the large amount of radioactivity involved and the heat that might be generated. The 1967 IAEA regulations then served as the basis for a major 1968 revision of the HMR relating to radioactive material and, concurrently, a major revision of 10 CFR Part 71 by the U.S. Nuclear Regulatory Commission (NRC). Those 1968 amendments, for the first time, brought both DOT and NRC regulations into essential conformity with the international standards. In 1973, IAEA made a complete revision of SS6. These changes included a new system, "A₁/A₂" system, for classifying radionuclides, replacing the former "transport group" system. The special characteristics of large sources were now considered routinely for all packages containing greater than a "Type A" quantity of radioactive material.

The 1973 IAEA standards also introduced the concepts for Type B packages, i.e., to determine the extent to which each country must approve a package design when an international shipment is involved. About ten years later, in 1983, DOT and NRC both adopted regulations which were in essential conformity with the 1973 edition of the IAEA requirements in Safety Series No. 6 (referred to in this Review as "SS6-73"). However, certain relatively minor exceptions and differences remained between the DOT and NRC regulations and the IAEA standards.

Just two years after the DOT revised the HMR to conform to the SS6-73 standards, IAEA again issued a comprehensive revision of SS6 in 1985. This edition was reprinted in 1990, with minor revisions. It is now referred to as the "1985 Edition, (As amended 1990)" (referred to in this review as "SS6-85 (1990)").

(In 1996, the contents of Safety Series 6 underwent a new revision which was renamed ST-1¹⁴ⁱ. Many of the provisions of ST-1 will eventually be incorporated into the U.S. radioactive material transport regulations; however, this review document reflects the U.S. regulations based on SS6-85 (1990).)

DOT's first version of this review document was issued in 1972, in the form of a special edition of DOT's "*OHM NEWSLETTER*". The first actual "Review" was issued in December, 1972, with subsequent revisions then issued in 1974, 1976, 1977, 1980, and

1983; the 1983^{19a} edition highlighted the DOT and NRC regulatory revisions to conform to SS6-73. This current Review highlights amendments to DOT's 49 CFR in Docket HM-169A and NRC's 10 CFR 71 which make the regulations conform to SS6-85 (1990).

II. REGULATORY SOURCES AND ORGANIZATIONS

A. ORGANIZATIONS

Under the Department of Transportation Act of 1966, DOT has regulatory responsibility for safety in the transportation of all hazardous materials, including radioactive material. This includes shipments by all modes of transport in interstate, intrastate, or foreign commerce (rail, highway, air, water), and by all means (truck, bus, auto, vessel, airplane, and rail-car, etc.) except for postal shipments. Postal shipments are under the jurisdiction of the U.S. Postal Service (USPS).

Prior to 1967, the Interstate Commerce Commission (ICC) had jurisdiction over both the safety and economic aspects of the transport of radioactive and other hazardous materials by surface modes. Jurisdiction over safety was transferred to DOT in April 1967. The modal administrations (FHWA, FRA, FAA, and USCG) each had separate regulations for the transportation of hazardous materials until 1974, when the Hazardous Materials Transportation Act (HMTA) was passed. At that time, a set of safety standards was developed that assured that properly prepared shipments would be acceptable for transport by all modes.

Under the Atomic Energy Act of 1954, as amended, the NRC also has responsibility for safety in the possession, use and transfer (including transport) of by-product, source, and special nuclear materials, e.g., "licensed material". Due to this overlap in statutory authorities of NRC and DOT, the two Agencies signed a 1979 Memorandum of Understanding (MOU) with regard to regulation of the transport of radioactive material⁸. The principal objective of the MOU was to avoid conflicting and duplicative regulations and to clearly delineate the areas in which each Agency establishes regulations.

Except for certain small quantities and specific products, a license is required from the NRC for possession and use of such materials. The NRC has promulgated, in 10 CFR Part 71, requirements which must be met by licensees for packaging used to deliver certain types of licensed material to a carrier for transport if fissile material or quantities exceeding Type A are involved. NRC also assists and advises DOT in the establishment of both national and international safety standards and in the review and evaluation of packaging designs. In 1979, NRC adopted by reference (10 CFR 71.5) portions of the DOT regulations, enabling NRC to inspect its licensees for compliance with DOT regulations applicable to shipper/licensees and to take enforcement actions on violations. Over half of the fifty and most of the industrial states have entered into formal agreements with the NRC whereby the NRC transfers to states the regulatory authority over licensed by-product, source, and less than critical quantities of special nuclear material (fissile materials). These "Agreement States", illustrated in **Figure 1**, have adopted uniform regulations pertaining to intrastate transportation of radioactive

material. Generally, these regulations require the shipper to conform to the packaging, labeling, placarding, and marking requirements of DOT. Many of the States have formally adopted the DOT regulations by reference for both intrastate and interstate transportation.

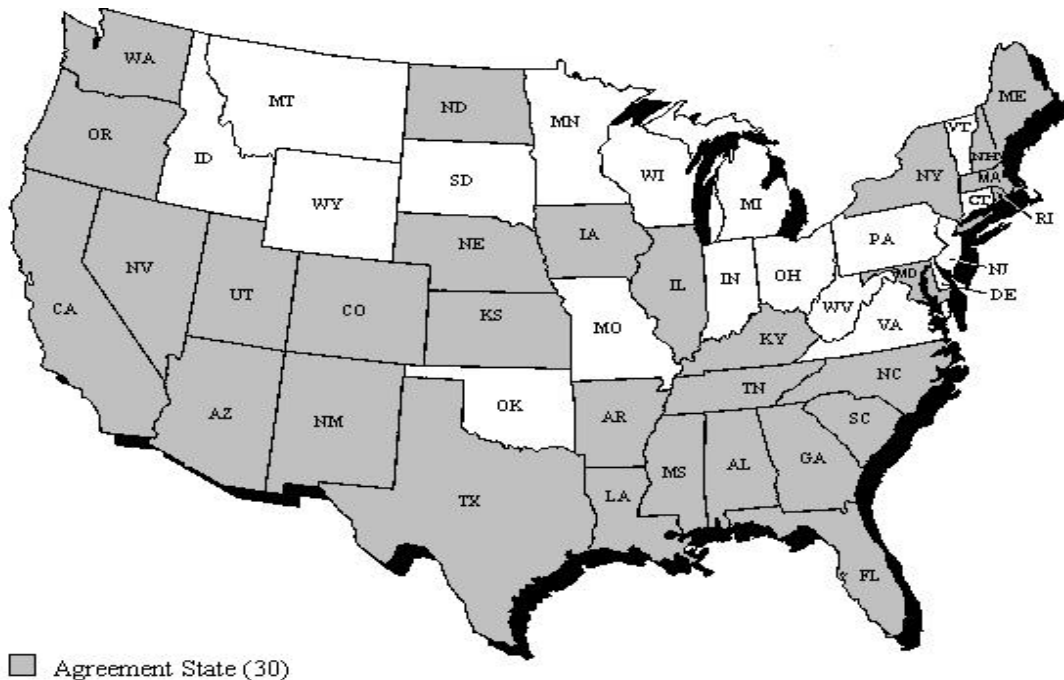
B. FEDERAL REGULATIONS

The regulations of the United States of America are published by three agencies: DOT, NRC, and the USPS. The principal sources of Federal regulations pertaining to the transportation of radioactive material are listed in Table 1. This Review is concerned primarily with the HMR as published in 49 CFR Parts 100-178. Persons involved as shippers, package designers, or carriers should maintain a current copy of the HMR. The HMR are published as of October 1st each year by the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 371954, Pittsburgh, PA 15250-1954.

Changes to the regulations are published in the daily Federal Register. Regulatory changes in the form of amendments or notices of proposed rulemakings are issued by the Research and Special Programs Administration (RSPA), DOT, and placed on the internet at <http://hazmat.dot.gov>.

Figure 1 - NRC Agreement States as of 1997

Note: Alaska and Hawaii are not Agreement States



Source: Nuclear Regulatory Commission

TABLE 1
SOURCES OF FEDERAL REGULATIONS

U.S. Department of Transportation (49 CFR)

49 CFR 106	Rulemaking procedures
49 CFR 107	Hazardous materials program procedures
49 CFR 171	General information, regulations, and definitions
49 CFR 172	Hazardous materials table, special provisions, hazardous materials communications, emergency response information, training requirements
49 CFR 173	Shippers-general requirements for shipments and packagings
49 CFR 174	Carriage by rail
49 CFR 175	Carriage by aircraft
49 CFR 176	Carriage by vessel
49 CFR 177	Carriage by public highway
49 CFR 178	Specifications for packagings

U.S. Nuclear Regulatory Commission (10 CFR)

10 CFR 20	Standards for protection against radiation
10 CFR 61	Licensing requirements for land disposal of radioactive waste
10 CFR 71	Packaging and transportation of radioactive materials

U.S. Postal Service (39 CFR)

39 CFR 124	Domestic Mail Manual, U.S. Postal Service Regulations (Postal Regulations for Transport of Radioactive Matter are also located U.S. Postal Service Publications #6 ⁹ , and 52, in the U.S. Postal Manual.)
------------	--

C. INTERNATIONAL REGULATIONS

There are a number of international bodies and organizations which deal with the transportation of radioactive material. The majority of these international bodies are sanctioned by or affiliated with the United Nations (UN). These agencies write regulations and recommend their adoption by member states as a basis for national regulations. The IAEA, located in Vienna, Austria, has been the primary body for the establishment of radioactive material regulations which have served as the basis of all other international regulations and requirements. The International Civil Aviation Organization (ICAO) is active in regulating¹⁶ the transport by air of dangerous materials, including radioactive material. The ICAO requirements have been adopted by nearly all countries. The International Air Transport Association (IATA), a body of member air carriers, also publishes regulations¹⁷ for air transport of restricted articles, including radioactive materials. Although IATA is not recognized in the DOT regulations, the ICAO requirements are essentially restated in the IATA regulations. For ocean vessel transportation, the International Maritime Organization (IMO) issues safety regulations¹⁸ for all types of hazardous materials, including radioactive material. The ICAO and IMO regulations reflect the United Nation's recommendations for all hazardous materials, which include the IAEA standards for radioactive material. The ICAO and IMO

regulations tend to provide more explicit requirements to shippers and carriers than the basic UN and IAEA standards. Table 2 lists the major sources of international regulations on transportation of radioactive material:

TABLE 2

AVAILABILITY OF INTERNATIONAL REGULATIONS

1. "Regulations for the Safe Transportation of Radioactive Materials", Safety Series #6, 1985 Edition (As Amended 1990) International Atomic Energy Agency (IAEA), Vienna, Austria. Available from Bernan Associates, 4611-F Assembly Drive, Lanham, MD. 20706-4391. (1-800-274-4888).
2. International Civil Aviation Organization (ICAO), Technical Instructions for the Safe Transport of Dangerous Goods by Air, 1997-98 Edition. Available from Document Sales Unit, ICAO, 1000 Sherbrooke St. West, Suite 400, Montreal, Quebec, Canada, H3A 2R2.
3. International Maritime Organization (IMO) Dangerous Goods (IMDG) Code. IMO Secretariat, Publication Section, 101-104 Piccadilly, London, England, U.K. W1V-OAE.
4. International Air Transport Association (IATA), Dangerous Goods Regulations, Available from IATA, Publications Assistant, 2000 Peel St., Montreal, Quebec, Canada, H3A 2R4.

D. OTHER DOMESTIC SOURCES OF REGULATIONS AND TARIFFS

A number of other organizations publish regulations or tariffs on the transportation of radioactive material and update them periodically throughout the year. Some of these are listed in Table 3. A tariff is **NOT** an official regulation. These tariffs are merely a publication by an organization or association which reprints certain Federal or International regulations. It shows the application and acceptance of those regulations by the carriers who participate in the tariffs. As such, tariffs are binding only on the organization or association or member carrier.

TABLE 3

OTHER DOMESTIC SOURCES OF REGULATIONS AND TARIFFS

1. "Official Air Transport Restricted Articles Tariff No. 6-D" and "Air Transport Restricted Articles Circular 6-D", Airline Publishing Co., Washington, DC.
2. "Hazardous Materials Regulations of the Department of Transportation, including Specifications for Shipping Containers", Association of American Railroads, Bureau of Explosives Publications, P.O. Box 1020, Sewickley, PA 15143.
3. "ATA Hazmat Transport Regs," Department of Transportation Regulations for Governing Transportation of Hazardous Materials by Air, Motor, Rail, and Water, Including Specifications for Shipping Containers", American Trucking Associations, Inc., Customer Service Section, 2200 Mill Road, Alexandria, VA.
4. "Chemical Regulation Reporter" and "Hazardous Materials Transportation", Bureau of National Affairs, 9435 Key West Avenue, Rockville, MD 20850.

NOTE: Users of these sources of regulations should ensure that they have the most current edition of the reference.

III. THE A₁/A₂ SYSTEM OF LIMITING PACKAGE ACTIVITY

A. DEFINITION OF RADIOACTIVE MATERIAL FOR PURPOSES OF THE TRANSPORTATION REGULATIONS (§173.403)

For purposes of transportation, radioactive materials are defined as those materials which spontaneously emit ionizing radiation and have a specific activity exceeding 70 Becquerel per gram of material (Bq/g), or 0.002 microcurie per gram of material ($\mu\text{Ci/g}$). Materials with a specific activity lower than 70 Bq/g (0.002 $\mu\text{Ci/g}$) and in which the activity is **essentially uniformly distributed** are not regulated by DOT or NRC for purposes of transportation. The limit of 0.002 microcuries per gram of material allows a distinction between materials of extremely low radioactivity, i.e., "EXEMPT" from regulation and those which are regulated as radioactive material for purposes of transportation.

Some materials which may be exempt from regulation during transportation still **might** be subject to licensing requirements of NRC, or an Agreement State with respect to use, possession, materials control or waste disposal; or they may be subject to EPA requirements as a hazardous substance or hazardous waste.

B. SI AND CUSTOMARY RADIOLOGICAL UNITS

U.S. policies and procedures for conversion to the metric system were formalized by the Metric Conversion Act of 1975 (Public Law 94-168, 15 USC 205a). The Act declared that U.S. policy shall be to coordinate and plan the increased use of the metric system. SI units for radioactive material quantities are part of the metric system. The 1985 IAEA regulations which DOT published in September 28, 1995, adopted the SI radiological units as the controlling units for transportation.

From a safety standpoint, the need for consistency in radioactive material packaging and activity identification is critical. Carriers and package handlers and all parties potentially having contact with the radioactive material package must be able to understand the units used in order to establish proper controls.

The change published in 1995⁶³ allowed limited continued use of the customary radiological units. The basic SI unit for quantity of radioactive material is the Becquerel (Bq), and the customary unit is the Curie (Ci). For radiation level, or dose rates, basic SI unit is the Sievert per hour (Sv/h), and the customary unit is Rem per hour (rem/h).

It is noted that the IAEA regulations as revised in 1996, will require that **only** SI units be used on shipping papers and labels¹⁴ⁱ. Shipping papers and labels for international shipments will be showing only SI units long before the time that SI units will be exclusively adopted for domestic shipments.

The information in **Appendix A** may be useful in converting values between SI Units and customary units.

C. A GOOD APPROACH FOR DETERMINING ACTIVITY LIMITS OF PACKAGES

The primary method to achieve safety in the transportation of radioactive material is the use of proper packaging for the specific radioactive material to be transported. In order to determine the packaging requirements, consider the following:

1. **What radionuclides are being shipped?** 49 CFR 173.435 lists the “A₁” and “A₂” values for approximately 400 specific radio nuclides. 49 CFR 173.433 provides “ground rules” for developing the values for unlisted, unknown, or mixtures of radionuclides. When using those ground rules, the shipper **must** obtain approval from DOT/RSPA for the use of any A₁ or A₂ value which has been derived by a shipper for an unlisted radionuclide [see §173.433(b)].
2. **What quantity of the radionuclides is being shipped?** The requirements are directly related to the total quantity of radioactivity in a package in terms of activity, e.g., Becquerel or “Bq”, Curies “Ci”, millicurie “mCi”, and microcuries “ μ Ci”.
3. **What is the form of the radionuclide?**
 - a. **Is the material in special form** (quantity is compared to A₁)?; or
 - b. **Is the material in normal form** (quantity is compared to A₂)?

D. A₁ AND A₂ QUANTITY LIMITS AND PACKAGING

The regulations use the A₁ and A₂ values as points of reference for quantity limits for each radionuclide. Each radionuclide is assigned an A₁ and an A₂ value. These two values (in Becquerel or curies) are the maximum activity of that radionuclide that may be transported in a TYPE A package. The A₁ value is the limit of activity for a particular special form radionuclide in a Type A package. The A₂ value is the limit for the amount of activity that can be transported in a type A package if the material is not in special form, i.e. "normal form". Table 4 gives examples of A₁ and A₂ values for a number of typical radionuclides.

The A₁ and A₂ values are used in the regulations as a normalized measurement of radiological risk for all radionuclides. Their uses go beyond the activity limits for Type A packages in determining when Type B packages must be used. Other uses involving large multiples of A₁ or A₂ or different fractions of A₁ or A₂ include:

- special routing of packages with large quantities
- total activity in packages and conveyances
- designating limits for packages excepted from most requirements
- designating specific activity of contaminated material and associated packaging

The derivation of the A₁ and A₂ values in the IAEA regulations is based on a series of dosimetric models, i.e., the "Q-system"^{14b}.

The limiting value for A₁ results from worst case assumptions of external direct gamma radiation levels from an unshielded source at a certain distance. Generally the A₁ value for a radionuclide is the quantity of that radionuclide that will result in a dose rate of 0.1 Sv/h (10 rem/h) at a distance of 1 meter.

The A₂ value, however, is based on the applicability of the most conservative worst case value for five different scenarios, which include the A₁ scenario plus external beta radiation to skin, inhalation, ingestion and external gamma radiation from immersion in a gaseous cloud of material released from a breached package.

As a result of an arbitrary limitation established by IAEA, no radionuclides have been assigned A₁ or A₂ values greater than 40 TBq (1080 Ci). However, based on their low specific activity and low toxicity, some radionuclides were assigned "unlimited" A₁ and A₂ values.

TABLE 4

TYPE A PACKAGE QUANTITY LIMITS FOR SELECTED RADIONUCLIDES

Table 4 is a selected listing of the A_1 and A_2 values for several typically transported radionuclides, taken from §173.435 (also see Table A-1 in 10 CFR 71 Appendix A):

Symbol of radionuclide	Element and Atomic number	A_1 TBq (Ci) (Special Form)	A_2 TBq (Ci) (Normal Form)
C ¹⁴	Carbon (6)	40 (1080)	2 (54.1)
Cs ¹³⁷	Cesium (55)	2 (54.1)	0.5 (13.5)
Ra ²²⁶	Radium (88)	0.3 (8.11)	0.02 (0.541)
Co ⁶⁰	Cobalt (27)	0.4 (10.8)	0.4 (10.8)
Ir ¹⁹²	Iridium (77)	1 (27)	0.5 (13.5)
Thorium (Natural)	Thorium(90)	Unlimited	Unlimited
Uranium (Natural)	Uranium (92)	Unlimited	Unlimited
Uranium (Enriched 5% or less)	Uranium (92)	Unlimited	Unlimited
Uranium (Enriched more than 5%)	Uranium (92)	10 (270)	0.001 (0.027)
Mo ⁹⁹	Molybdenum (42)	0.6 (16.2)	0.5 (13.5 ^(a))

(a) 0.74 TBq (20 Ci) for domestic shipments

E. SPECIAL FORM RADIOACTIVE MATERIAL (A_1)

Special form materials are limited to those materials which, if released from a package, would present a hazard due to direct **external radiation only**. Usually, due to the high physical integrity of a special form material, radioactive material contamination is not expected even under severe accident conditions. This high physical integrity is occasionally the result of **inherent natural** properties of the material, such as its being in nondispersible solid form. Most often, however, it is an **acquired characteristic**, resulting from being welded (encapsulated) into an extremely durable metal capsule.

The table in §173.435 of the DOT regulations lists the A_1 and A_2 values for most radionuclides that are transported. For each radionuclide, both the A_1 values for materials in special form and the A_2 values for materials in normal form are listed in both becquerels (Bq) and curies (Ci). The A_1 and A_2 quantities for each radionuclide are basically the maximum activity that can be transported in a type A package. For many radionuclides, the regulations allow substantially larger quantities of special form material to be placed in a Type A packaging than when the material is in "normal form", i.e., "non-special form".

Special form radioactive material is defined in 49 CFR 173.403. Special form sources must have at least one external physical dimension which exceeds 5 mm (0.197"). The minimum dimension requirement makes the capsule easier to see and recover in the

event of its release from the package during an accident. Special form encapsulations are required to be constructed in a manner that they can only be opened by destroying the capsule. This requirement prevents the inadvertent loosening or opening of the capsule, either during transport or following an accident. The testing requirements for determination of whether radioactive materials qualify as "special form" are found in 49 CFR 173.469, which describes tests for high temperature, impact, percussion, bending, and leakage.

Figure 2 - "Special Form" Radioactive materials [§§173.403 and 173.469]

The following descriptions are for the Figure 2 illustrations on the next page. These illustrations display several typical special form radioactive material sources. The illustrated encapsulations are representative of commonly transported sources with significant radioactive content, and the dimensions and activity indicated are typical.

A) **Neutron Source** (drawing shows empty inner and outer capsules with plugs to be welded for sealing) Dimensions: 30 mm O.D. by 60 mm; Content: Am-241/Be, 0.7 TBq (20 Ci).

B) **Density/Transmission Source** (Cutaway drawing shows both inner and outer capsules) Dimensions: 8 mm O.D. by 12 mm; Content: Cs-137, 2 GBq (50 mCi).

C) **Industrial Radiography Source** (with 15 cm connector cable "pigtail") Dimensions: 5 mm O.D. by 15 mm; Content: Ir-192, 4 TBq (100 Ci).

D) **Sterilizer/Process Irradiator Source** Dimensions: 16 mm O.D. by 450 mm; Content: Co-60, 740 TBq (20,000 Ci).

Figure 2 - "Special Form" Radioactive Material [§§173.403 and 173.469]



Figure A-Neutron Source

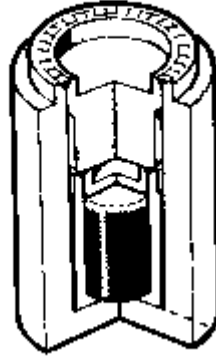


Figure B-Density/Transmission Source

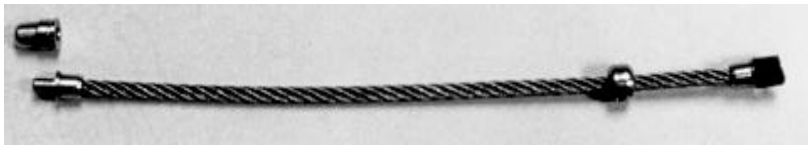


Figure C-Industrial Radiography Source

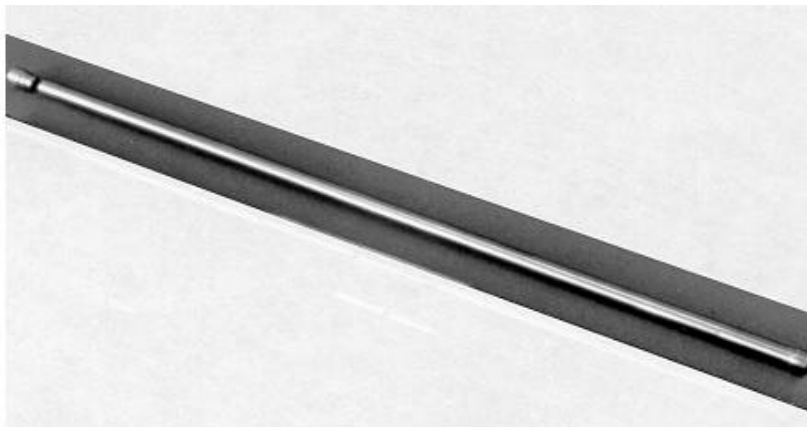


Figure D-Sterilizer/Process Irradiator Source

Special form package activity limits are stated in terms of "A₁".

For purposes of import or export, a shipper must furnish the carrier and the foreign consignee a certificate of Competent Authority for the special form material. For domestic shipments, DOT does not require special form certificates when offering the material as special form. However, the shipper must have evidence that the source, if offered as special form radioactive material, meets special form standards. A special form certificate issued by DOT or by a foreign competent authority is acceptable

evidence of a source being special form. Special form source manufacturers or suppliers often provide customers with "Special Form Certificates of Competent Authority". The requirements for certification of special form sources are in 49 CFR 173.476.

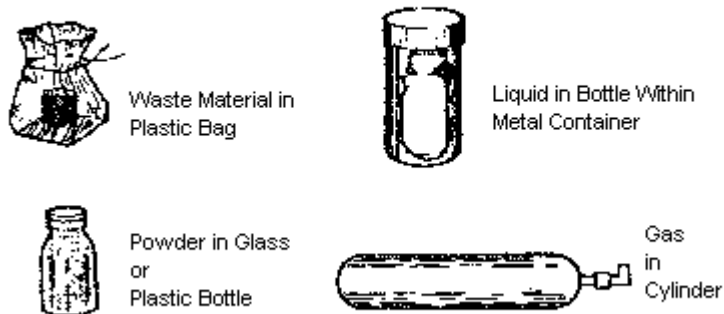
NOTE: An encapsulated sealed source need not be subjected to the **impact** and **percussion** tests of §173.469(b)(1) and (2), provided that it satisfies the Class 4 impact test prescribed in International Organization for Standardization document ISO 2919-1980(e), "Sealed Radioactive Sources Classification". Also, it need not be subjected to the **heat** test of §173.469(b)(4), provided it satisfies the Class 6 temperature test specified in ISO 2919-1980(e).

F. NORMAL FORM RADIOACTIVE MATERIAL (A₂)

As defined in §173.403, normal form radioactive material means a Class 7 material which does not qualify as a "special form Class 7 material". Illustrated in Figure 3 are typical physical forms for normal form radioactive material.

**FIGURE 3-NORMAL FORM RADIOACTIVE MATERIAL
(49 CFR 173.403)**

Normal Form Materials may be solid, liquid, or gaseous and include any material which has not been qualified as Special Form



Normal (non-special) form package activity limits are stated in terms of "A₂"

G. HIGHWAY ROUTE CONTROLLED QUANTITIES

A "Highway Route Controlled Quantity" (HRCQ) requires Type B packaging, and has certain highway routing limitations and requirements [49 CFR 173.403 and 397.101(b) (Federal Motor Carrier Safety Regulations)].

The HRCQ applies to the content of a single package - not to the sum of contents of all packages, i.e., in a shipment which exceeds:

- (1) 3000 times the A_1 value of the radionuclide as specified in §173.435 for special form Class 7 material; or
- (2) 3000 times the A_2 value of the radionuclide as specified in §173.435 for normal form Class 7 materials; or
- (3) 1000 TBq (27,000 Curies), whichever is least.

How to determine if a package contains a HRCQ of material:

1. Identify the radionuclide being transported.
2. Determine if it is in special form or normal form.
3. For example: A package contains 777 TBq (21,000 Curies) of Cobalt-60 in special form. The A_1 value for Cobalt-60 is 0.4 TBq (10.8 Curies). 3000 times 0.4 TBq (10.8 Curies) = 1200 TBq (32,900 Curies). This value of 1200 TBq is greater than 1000 TBq (27,000 Curies), therefore, the 777 TBq (21,000 Curie) quantity should be compared to 1000 TBq (27,000 Curies). Since the amount in the package does not exceed this, the amount in the package is not a HRCQ.
4. If the contents of the package being shipped are determined to be a HRCQ, the package must be transported under specific routing controls:
 - (a) The carrier must operate on "preferred routes" that conform to §397.101(b) of the Federal Motor Carrier Safety Regulations.
 - (b) The carrier is required to prepare a written route plan and furnish a copy to the driver and the shipper (before departure for exclusive-use shipments and within 15 days following departure for all other shipments).
 - (c) Carriers of HRCQ must also file detailed reports to the Associate Administrator for Motor Carriers, Office of Safety and Technology, Federal Highway Administration (FHWA), within 90 days of accepting the packages for shipment. The report must include route plans, shipping papers, names of shippers, carriers and consignees, etc. [49 CFR 397.101(g)] (Shipments made in compliance with the physical security requirements of 10 CFR 73 of NRC are excepted from this requirement.)
 - (d) The driver of a HRCQ shipment must be provided with certain training every two years and must have in his possession a certificate of such training.

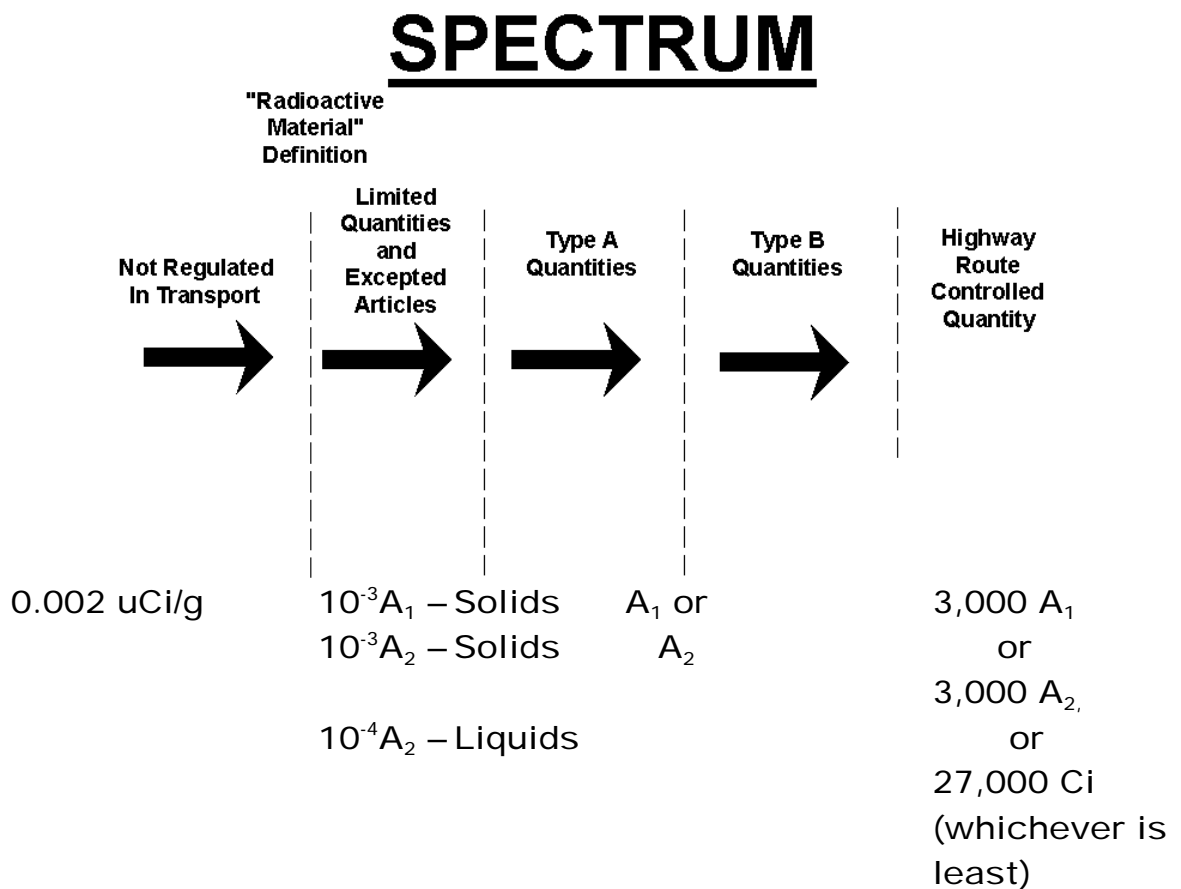
NOTE: The NRC regulations require that licensees shipping nuclear waste in Type B packages provide advance notification to State Governors or their designated representative. There are other advance notification requirements for shippers of spent nuclear fuel and special nuclear materials [see 10 CFR 71.97 and 73.72].

H. THE A₁/A₂ SPECTRUM OF PACKAGE ACTIVITY LIMITS

The application of the A₁ and A₂ values to define excepted, Type A, Type B, and HRCQ is illustrated in the diagram below (Figure 4). This diagram begins on the left with the definition of radioactive material, **for purposes of transportation**. The increasing multiples of A₁ and A₂ values are indicated toward the right for excepted, Type A, Type B and HRCQ packages.

NOTE: Low specific activity (LSA) and surface contaminated objects (SCO) categories are not illustrated in this diagram. These are discussed in Section VI.

FIGURE 4



IV. RADIATION AND CONTAMINATION LIMITS

A. PACKAGE RADIATION LIMITS

The limits on radiation levels of a package offered for transportation are found in 49 CFR 173.441(a). They are illustrated in Figure 5, and Table 5 gives information on package radiation level limits and package stowage restrictions. These, in turn, are illustrated in Figure 6, for radioactive material packages in a non-exclusive use vehicle.

FIGURE 5-Graphical Illustration of Limits on Package Radiation Levels

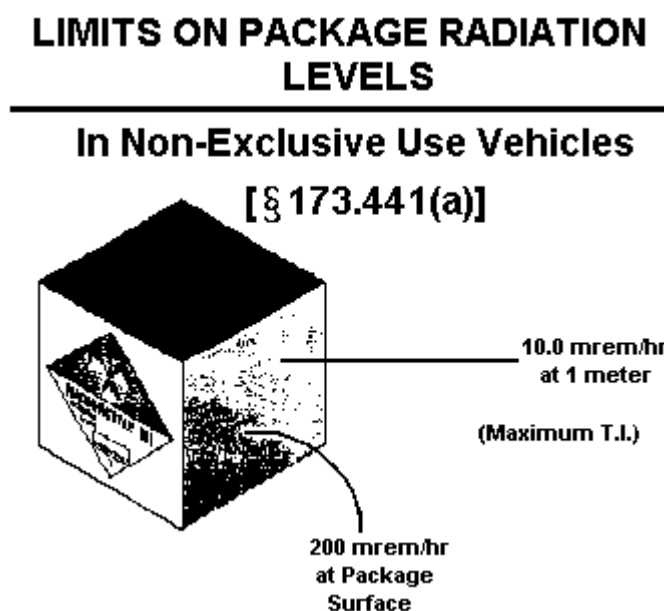


TABLE 5

RADIATION LEVEL LIMITS-PACKAGES IN NON-EXCLUSIVE USE CONVEYANCES AND PACKAGE STOWAGE RESTRICTIONS

Packages [§173.441(a)]

- 10 mrem/hr (0.1 mSv/h) at one meter
- 3 mrem/hr at one meter (0.03 mSv/h) if package is intended for shipment on passenger-carrying aircraft [§175.700 (a), §173.448 (e)]
- 200 mrem/hr (2.0 mSv/h) at any point on package surface

Package Stowage Restrictions

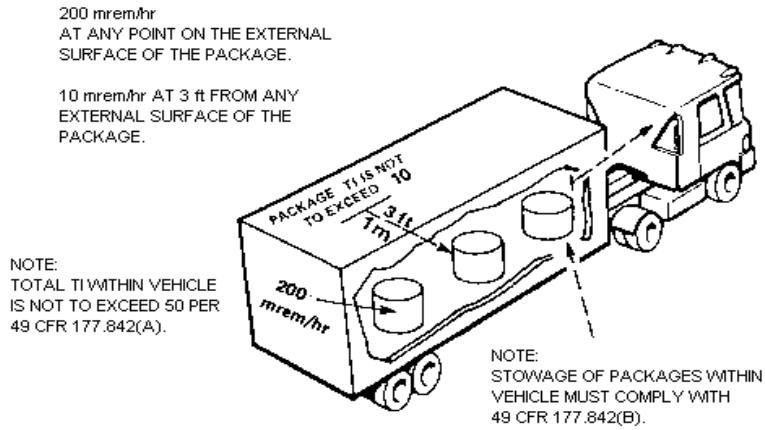
- Total of 50 TI (sum of individual package transport indexes) in vehicle or storage area group;
- Each group of packages must be stowed at least 20 ft. (6 m) from other groups of radioactive packages; and
- Each package/group must be stowed at prescribed distances from areas occupied by persons, based on tables of cumulative TI versus separation distance found in DOT carrier regulations as follows:

Rail	§174.700
Air	§175.700
Water	§176.708
Highway	§177.842

NOTE: See also §173.447 for stowage incidental to transportation.

FIGURE 6

49 CFR 173.441(a)



NON-EXCLUSIVE USE OPEN OR CLOSED TRANSPORT

B. DEFINITION OF THE TRANSPORT INDEX (49 CFR 173.403)

The transport index, often called the TI, is the dimensionless number (rounded up to the first decimal place, i.e., tenths) placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation. The TI of the package must be indicated in the rectangular TI block in the lower half of the Category II and III Yellow RADIOACTIVE labels [see Section IV.E]. The TI is the key parameter used by the carrier for stowage distance control of radioactive packages in non-exclusive use vehicles.

How to determine the TI:

1. Based on the radiation level for non-fissile material packages, multiply 100 times the maximum radiation level in millisievert(s) per hour at one meter (3.3 feet) from the external surface of the package;
2. Based on the nuclear criticality safety evaluation, divide 50 by the allowable number of packages which may be transported together;
3. The applicable TI is the higher of the above two values.

In either case, the maximum allowable TI on a fissile material package is 10 (unless the package is shipped in a "fissile material, controlled shipment").

C. EXCLUSIVE-USE SHIPMENT RADIATION LIMITS

The package limits stated above (except for certain exclusive-use **closed** transport vehicles) also apply to exclusive use shipments. In this case, these limits are

supplemented by limits on the radiation level from the transport vehicle itself [see 49 CFR 173.441(b)].

The practical application of the package and vehicle radiation limits of §173.441(b) are illustrated in Figures 7, 8, and 9. TI limits for freight containers and conveyances aboard vessel are shown in Table 6 [see 49 CFR 176.704(a)].

**FIGURE 7
RADIATION LIMITS-CONVENTIONAL CLOSED EXCLUSIVE-USE VEHICLE**

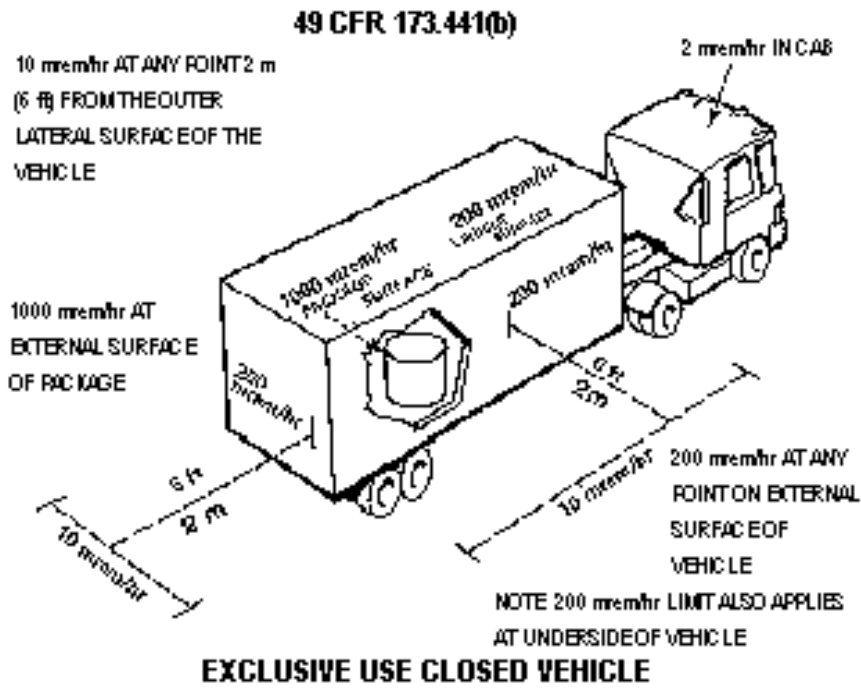
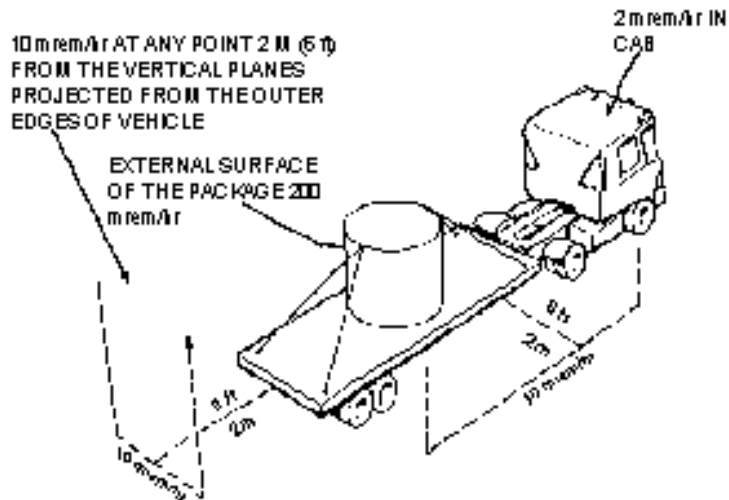


FIGURE 8
RADIATION LIMITS - OPEN EXCLUSIVE USE FLATBED VEHICLE WITHOUT
ENCLOSURE

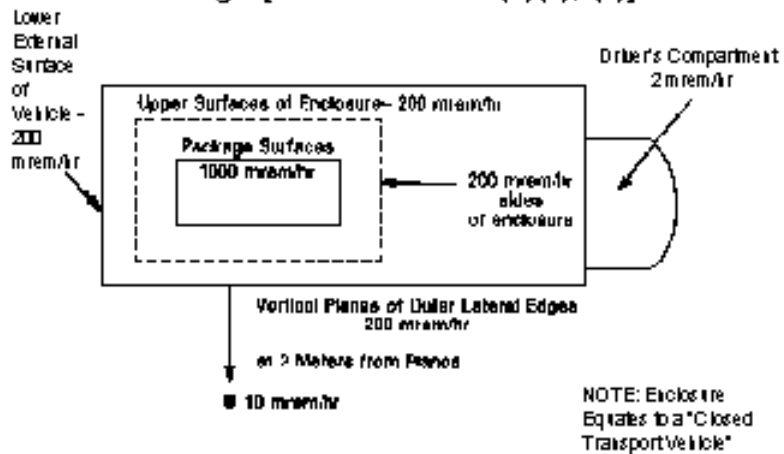
49 CFR 173.441(b)



EXCLUSIVE USE OPEN TRANSPORT
 WITHOUT ACCESS-LIMITING OUTER ENCLOSURE

FIGURE 9
RADIATION LIMITS, OPEN EXCLUSIVE-USE FLATBED VEHICLE WITH
ENCLOSURE

Open Flatbed, Exclusive Use Vehicle with an
Exterior Access-Limiting Enclosure about the
Package [49 CFR 173.441(b)(2), (3)]



**TABLE 6
TRANSPORT INDEX LIMITS FOR FREIGHT CONTAINERS
AND CONVEYANCES ABOARD VESSELS**

TABLE III LIMITS FOR FREIGHT CONTAINERS AND CONVEYANCES

Type of freight container or conveyance	Limit on total sum of transport indexes in a single freight container or aboard a conveyance			
	Not under exclusive use		Under exclusive use	
	Non-fissile material	Fissile material	Non-fissile material	Fissile material ^a
Freight container – Small.....	50.....	50.....	N/A.....	N/A
Freight container – Large.....	50.....	50.....	No limit	100 ^b .
Vessel ^c				
1. Hold, compartment or defined deck area:				
Packages, overpacks, small freight containers.....	50.....	50.....	No limit	100 ^b .
Large freight containers.....	200 ^d	50.....	No limit	100 ^b .
2. Total vessel:				
Packages, etc.....	200 ^d	200 ^d	No limit ^e	200 ^e .
Large freight containers.....	No limit ^d	No limit ^d	No limit	No limit ^d .

^a Provided that transport is direct from the consignor without any intermediate in-transit storage, where the total TI exceed 50.

^b In cases in which the total TI is greater than 50, the consignment must be so handled and stowed so that it is always separated from any package, overpack, portable tank or freight container carrying Class 7 (radioactive) materials by at least 6 meters (20 feet).

^c For vessels the requirements given in 1 and 2 must be fulfilled.

^d Provided that the packages, overpacks, portable tanks or freight containers, as applicable, are stowed so that the total sum of the TI's in any group does not exceed 50, and that each group is handled and stowed so that the groups are separate from each other by at least 6 meters (20 feet).

^e Packages or overpacks carried in or on a transport vehicle which are offered for transport under the provisions of §173.441(b) of this subchapter may be transported by vessel provided that they are not removed from the vehicle at anytime while on board the vessel.

NOTE: References for exclusive use shipments, are NRC Information Notice No. 80-32⁴⁴ and 80-32 (Rev. 1)⁴³. "Clarification of Certain Requirements For Exclusive-Use Shipments of Radioactive Materials".

D. CONTAMINATION LIMITS AND CONTAMINATION SURVEYS

The level of removable (non-fixed) surface radioactive contamination on a package of radioactive material must not exceed the limits set forth in Table 11 of 49 CFR 173.443 which is restated below as TABLE 7.

TABLE 7

Non-fixed external Radioactive Contamination Wipe limits

Contaminant	Maximum permissible limits		
	Bq/cm ²	uCi/cm ²	dpm/cm ²
Beta and gamma emitters and low toxicity alpha emitters	0.4	10 ⁻⁵	22
All other alpha emitting radionuclides	0.04	10 ⁻⁶	2.2

The contamination limits of Table 11 of 49 CFR 173.443 apply to all non-exclusive use shipments of radioactive material packages. For packages shipped as exclusive-use shipments by rail or highway, the removable (non-fixed) radioactive surface contamination at any time during transport may not exceed 10 times the limits for non-exclusive use shipments.

At the beginning of transport the levels may not exceed those in Table 11. If nonfixed surface contamination levels on packages in an exclusive use vehicle have risen during transportation above the Table 11 limits, the transport vehicle must be surveyed with appropriate radiation detection instruments after each use. It shall not be returned to service until the external radiation on the surface is below 0.005 mSv per hour (0.5 mrem per hour) and the removable surface contamination is below the limits of Table 11. An exception to this vehicle survey requirement applies to closed highway or rail transport vehicles which are dedicated solely to the transport of radioactive packages and are appropriately marked, on the exterior, as dedicated vehicles "For Radioactive Materials Use Only". In such cases the removable surface contamination on the packages may be as high as the "factor of 10" limit at the beginning of transport.

In applying the contamination limits, the key parameter is the activity measured on "wipe" or "smear" samples of the removable (non-fixed) surface contamination. 49 CFR 173.443(a)(2) provides for use of other methods of assessment of equal or greater efficiency, provided that the instant efficiency is taken into account; non-fixed surface contamination must not exceed ten times the limits of Table 11 of §173.443.

NOTE: NRC Information Notice No. 85-46⁴¹, "Clarification of Several Aspects of Removable Surface Contamination limits For Transport Packages" may serve as a reference tool.

V. CATEGORIES OF RADIOACTIVE MATERIAL PACKAGES

A. BASIC PRINCIPLE OF RADIOACTIVE MATERIAL PACKAGING

Fundamental to a good understanding of radioactive material transportation safety and packaging requirements is the basic premise that:

Safety in transportation of radioactive material primarily depends upon use of the proper packaging for the type, quantity and form of radioactive material transported. Additionally, packaging design is performance oriented with packaging durability being dictated by the potential hazards of the radioactive content.

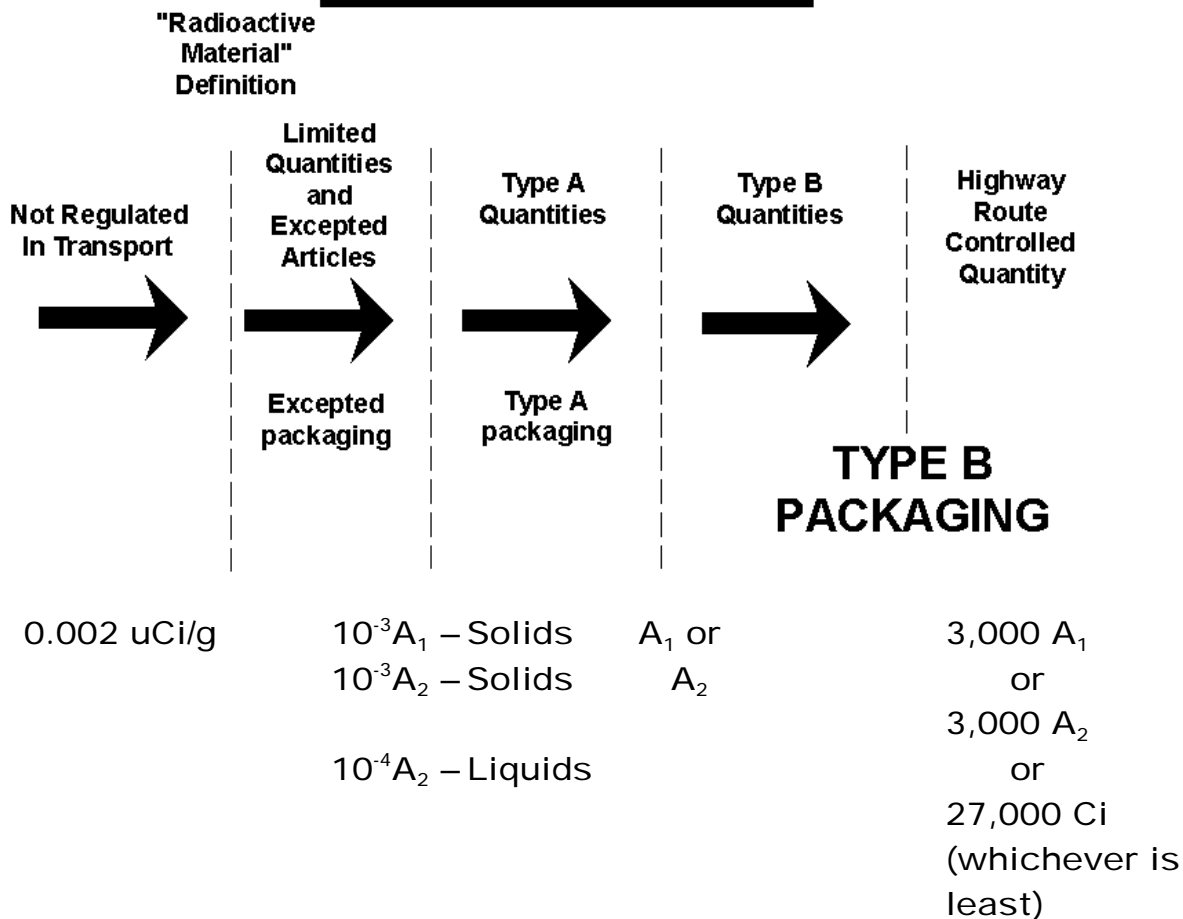
There are essentially five categories of radioactive material packagings. Development of the technical criteria for each packaging category is correlated to certain general and performance requirements. The categories include:

1. Excepted packaging; which includes "strong tight" packaging
2. Type A packaging
3. Type B packaging
4. Industrial Packaging (IP-1, IP-2, IP-3)
5. Fissile material packaging (Type AF, Type IF, and Type B(U)F and B(M)F)

Figure 10 repeats the previously illustrated A₁ and A₂ Threshold continuum, but adds the three basic packaging categories.

FIGURE 10
THE TRANSPORT PACKAGE ACTIVITY SPECTRUM
 (With Packaging References)

THE TRANSPORT ACTIVITY SPECTRUM



B. GENERAL PACKAGING REQUIREMENTS

Unless excepted, all packages are subject to applicable general requirements in 49 CFR 173 Subparts A and B, as well as §173.410 "General Design Requirements".

1. Part 173, Subparts A and B: Shipper and package designers should review §§173.24 (General design requirements for packagings and packages) and 173.24a (Additional Design Requirements for non-bulk packagings and packages) to determine which requirements apply. It is to be noted that, for radioactive material, the definition of "packaging" does not have a volume or capacity requirement as indicated in §171.8.

2. §173.410 (General design requirements): Shippers and package designers must recognize that the requirements of §173.410 must be considered for all radioactive material packages. However, all requirements do not apply to all packages, which is obvious considering the diversity of packages covered by the regulation. An example of a requirement that is applicable to all packages is the performance capability requirement for vibration of §173.410(f). Some persons have erroneously considered this to mean that all packages must be vibration-tested in a laboratory. Demonstrating compliance by methods other than testing is allowed in §173.461(a)(4). Furthermore, DOT has provided letters of interpretation that the vibration requirement of §178.608 is a performance capability requirement that may be reasonably satisfied by documented evidence that packages of a particular design have been transported extensively without failure.

Each of the packaging categories (excepted, industrial, fissile, Type A, and Type B) is separately discussed in paragraphs C-G below.

C. CATEGORIES OF EXCEPTED PACKAGES

Table 8 represents the §173.425 "Table of Activity Limited Quantities, Instruments, and Articles". These limits apply to instruments, articles and limited quantities which are subject to the exceptions in §§173.421 and 173.424. In this table, multiples of the A_1/A_2 values are used as the basis for defining the package activity limits. Packages containing materials within these quantity limits are excepted from specification packaging, marking, labeling, and shipping paper requirements. However, they are not exempt from regulation during transportation as would be materials having a specific activity of less than 70 Bq/gm (0.002 μ Ci/gram), i.e., not meeting the definition of "radioactive material" for purposes of transportation.

**TABLE 8
ACTIVITY LIMITS FOR EXCEPTED PACKAGES**

Nature of contents	Instruments and articles		Materials package limits ¹
	Limits for each instrument or article ¹	Package Limits ¹	
Solids:			
Special form	$10^{-2} A_1$	A_1	$10^{-3} A_1$
Normal form	$10^{-2} A_2$	A_2	$10^{-3} A_2$
Liquids:			
Tritiated water:			
<0.0037 TBq/liter (0.1 Ci/L)			37 TBq (1,000 Ci)
0.0037 TBq to 0.037 TBq/L (0.1 Ci to 1.0 Ci/L)			3.7 TBq (100 Ci)
<0.037 TBq/L (1.0 Ci/L)			0.037 TBq (1.0 Ci)
Other Liquids	$10^{-3} A_2$	$10^{-1} A_2$	$10^{-4} A_2$
Gases:			
Tritium ²	$2 \times 10^{-2} A_2$	$2 \times 10^{-1} A_2$	$2 \times 10^{-2} A_2$
Special form	$10^{-3} A_1$	$10^{-2} A_1$	$10^{-3} A_1$
Other form	$10^{-3} A_2$	$10^{-2} A_2$	$10^{-3} A_2$

¹ For mixtures of radionuclides see §173.433(d).

² These values also apply to tritium in activated luminous paint and tritium absorbed on solid carriers.

Excepted packages must meet the following:

1. The general design requirements cited in paragraph B above;
2. Non-fixed contamination limits on package surfaces must not exceed the limits of §173.443(a);
3. The radiation level at any point on the surface of the package must not exceed 0.005 mSv/hour (0.5 mrem/hour);
4. The outside of the inner packaging, or if there is no inner packaging, the outside of the package itself must bear the marking "RADIOACTIVE", except for instruments or article, or empty packaging;
5. For instruments or articles, the radiation level at four inches from any point on the surface of the unpackaged instrument or article may not exceed 0.1 mSv/hour (10 mrem/hour);
6. In lieu of a specific shipping paper, a prescribed certification statement referencing the applicable exception paragraph must be included "in", "on", or "with" the package.

The specific sections of 49 CFR for the various categories of excepted radioactive packages include:

§173.421 Excepted packages for limited quantities of Class 7 radioactive material

§173.422 Additional requirements for excepted packages containing Class 7 radioactive material

§173.423 Requirements for multiple hazard limited quantity Class 7 radioactive material

§173.424 Excepted packages for radioactive instruments and articles

§173.426 Excepted packages for articles containing natural uranium or thorium

§173.428 Empty Class 7 radioactive material packaging

EMPTY PACKAGES

The EMPTY package provision provides exceptions from certain requirements for a radioactive material packaging which has been emptied of its radioactive contents as far as practicable, but still contains residual radioactivity. This residual radioactivity limit, however, is not quantified or stated in terms of activity content, but rather in terms of internal contamination in units of activity per cm². Such internal contamination is limited to 100 times the removable (non-fixed) contamination limits for exterior package surfaces. Wipe contamination sampling techniques are often not practical or feasible for the interior of the containment system of some radioactive material packages.

POSTAL SHIPMENTS

Under USPS rules for "allowable radioactive matter", packages which meet the applicable 49 CFR requirements for excepted packages may also be mailed in the Postal system. HOWEVER, there is a very important additional restriction, the amount of radioactivity in a mailable package must be limited to one tenth of the values listed in Table 8. Additional restrictions may apply to mailable radioactive packages, therefore, before mailing a radioactive material package, one should consult the U.S. Postal Publication # 6⁹ requirements. For international postal shipments, the Postal requirements of the receiving country should also be reviewed, since certain nations do not allow postal shipments of radioactive matter. Also, international postal shipments of radioactive material require the exterior marking "**RADIOACTIVE**".

D. TYPE A PACKAGES

Type A packaging must comply with the applicable general packaging requirements of §§173.24, 173.24(a), and 173.410, and the additional requirements of §§173.412, and 173.415. These packagings must prevent the loss or dispersal of the radioactive contents and maintain the radiation shielding properties during normal conditions of transportation, which include rough handling conditions, for which tests are specified in 49 CFR §173.465. These rough handling conditions include:

Water Spray Test, which simulates the package having been left in the rain for a period of 30 minutes, followed by;

Drop Test of 4 feet onto a hard surface, in a most damaging orientation - simulating falling off a vehicle or loading platform.

Puncture Test with a 13 pound steel rod being dropped onto the damp package - simulating a loose object hitting the package.

Crush Test equal to a force of at least 5 times the weight of the package - simulating the damp package being at the bottom of a stack of packages.

The performance requirements for type A packages containing liquids and gases are more stringent than the requirements for solids, because of the greater potential for materials spreading if the package containment system fails. The more stringent

requirements relate to containment, and the height in the drop tests, and are found in §173.412 (k) and §173.466.

Essentially, the only authorized Type A package in the DOT regulations is the DOT specification 7A, which is based **totally** on performance test conditions rather than on hardware or design requirements. This provides the package designer with maximum latitude in the use of engineering creativity to produce optimally useful and economic designs. Using any of the methods authorized in §173.461, each shipper of a DOT-7A package must determine if the DOT-7A design meets the performance requirements in §§173.412 and 173.465, and then must document and maintain this evaluation or "self-certification" on file for at least one year after the last shipment. Consequently, each design must be specifically certified as meeting the DOT-7A requirements. Each time the contents change, or the packaging components change (i.e., content weight, material form, closure, etc.), the performance capability of the modified package must be re-evaluated with respect to the requirements before the Type A designation may be assigned.

DOT-7A designs do not require the approval of either DOT or NRC, for domestic shipment or for international transportation of non-fissile radioactive material. Imported packages which are marked with Type A and the country of origin, and meet the standards of SS6-85 (1990), are acceptable for import shipments. If such packages are to be used for domestic shipments, the domestic shipper must obtain and maintain on file the applicable Type A evaluation and documentation performed by the foreign package designer.

A reference document⁵¹ which may be useful for evaluating existing DOT-7A designs is WHC-EP-0558. This document is also available on the internet at <http://www.hanford.gov/pss/t&p/dot7a/pdot7a.htm>. **CAUTION**-the information in that document should be supplemented with the shippers additional comparative analysis of his package design parameters and specific contents relative to the surrogate contents of the test document.

There has been some confusion about the last sentence in §173.415(a) concerning some of the old package designs not being authorized for use after April 1, 1997. Simply stated, for any 7A to be authorized for use, the shipper must insure that his evaluation data (regardless of the date of the test) satisfies the current performance requirements of §§173.412 and 173.465.

FIGURE 11-TYPICAL TYPE A PACKAGING CONFIGURATIONS

The following are descriptions for the Figure 11 illustrations on the next page. These illustrations display several Typical Type A Packaging Configurations. The package measurements and activities shown are representative.

- A) **Molybdenum 99 Generator** (Cutaway shows outer carton, foam spacer, shielding, ion column, and tubing for saline solution); Dimensions: 35 cm cube; Weight: 18 kg; Contents: Mo-99 and Tc-99m, 0.15 TBq (4 Ci).
- B) **Moisture Density Gauge & Carrying Case** Dimensions: 20 cm by 13 cm by 10 cm, handle is 30 cm in length, case is 30 cm by 20 cm by 15 cm; Weight: 11 kg; Contents: special form, Am-241/Be, 2 GBq (50 mCi) and Cs-137, 0.4 GBq (10 mCi).
- C) **Steel Drum** (55 Gallon) Dimensions: 60 cm by 90 cm; Weight: 200 kg; inside packaging configurations and radioactive contents vary widely; Contents: many radionuclides, 0.1 GBq to 40 TBq (3 mCi to 1000 Ci).
- D) **Wooden Box** Dimensions: rectangular/0.2 to 4 m; Weight: 2 kg to 1000 kg; inner packaging varies widely depending on weight and form of content; Contents: many radionuclides (special and normal form), 0.1 GBq to 40 TBq (3 mCi to 1000 Ci).
- E) **Nuclear Pharmacy unit dose(s) package** (Ammo Box) Dimensions: 30 cm by 23 cm by 15 cm; Weight: 8 kg; Contents: Tc-99m, Ga-67, Tl-201, I-131, 0.1 to 10 GBq (3 to 270 mCi).
- F) **Carton for Medical/Research Radionuclide in Liquid form** (drawing shows: carton, foam spacer, shielding, secondary container, absorbent and primary container) Dimensions: 20 cm to 50 cm cube; Weight: 2 kg to 25 kg; Contents: many radionuclides, 10 MBq to 40 TBq (0.3mCi -1000 Ci).

FIGURE 11-TYPICAL TYPE A PACKAGING CONFIGURATIONS

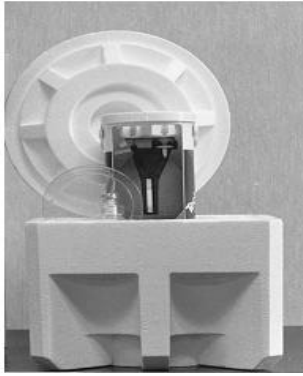


Figure A-Molybdenum 99 Generator

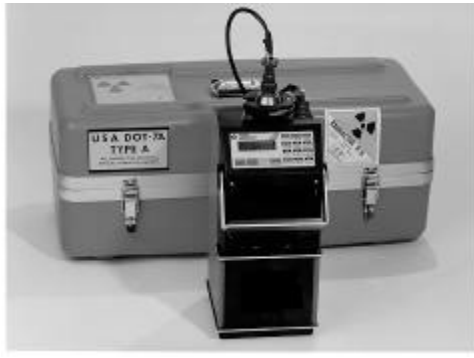


Figure B-Moisture Density Gauge & Carrying Case



Figure C-Steel Drum

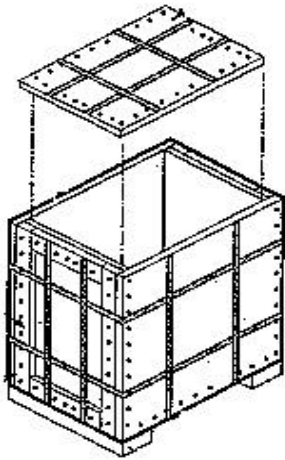


Figure D-Wooden Box



Figure E-Nuclear Pharmacy Unit Dose(s) Package

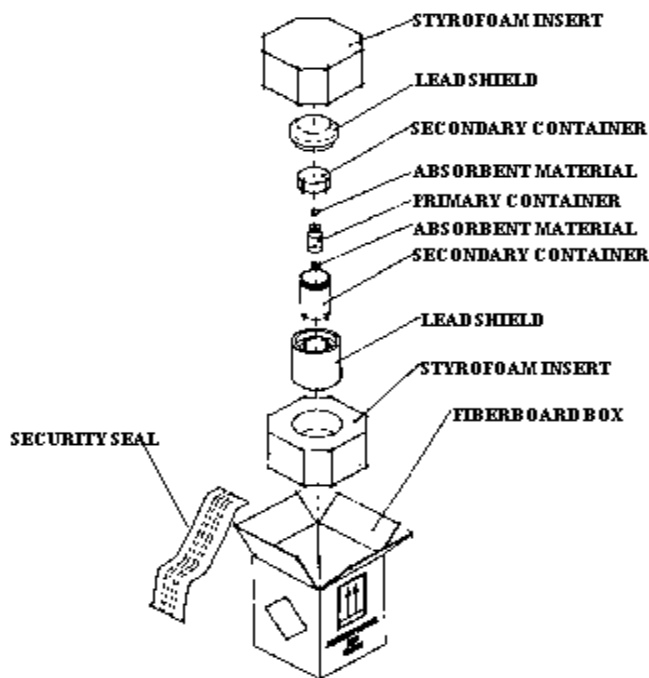


Figure F-Carton for Medical/Research Radionuclide in Liquid Form

E. TYPE B PACKAGES

1. Package Test Standards

Type B packaging must meet the general packaging and performance standards for Type A packages and additionally must have the ability to survive serious accident damage tests (hypothetical accident conditions). After testing, there may be only a very limited loss of shielding capability and no loss of containment, as measured by leak-rate testing of the containment system of the package. The performance criteria which the package designer must use to assess his Type B package design against the established hypothetical accident conditions are prescribed in 10 CFR 71.73 of the NRC regulations and include the following sequential tests:

- i. A 30-foot free fall of the test package onto an unyielding surface;
- ii. If applicable, for certain contents and package density, subjecting the test specimen to a dynamic crush test by positioning the specimen on a flat unyielding horizontal surface so as to suffer maximum damage by the drop of a 500 kg. (1100 lbs.) steel plate mass from 9 meters (30 ft) onto the test package.
- iii. A puncture test as a free drop of the test package from a height of 1 m (40 in) onto a 15 cm (6 in) diameter vertical steel peg;

- iv. Exposure to a thermal environment of 800°C (1475°F) for 30 minutes;
- v. Water immersion of the test package under at least 15 meters (50 ft.) depth and;
- vi. For fissile packages where water in-leakage is not assumed in the criticality analysis, immersion of the test package under a head of water of at least 0.9 meters (3 ft)

NOTE: NRC Regulatory Guides²³ in Division 7-Transportation are reference resources relative to the engineering tests listed above (Regulatory Guides 7.3, 7.4, 7.6, 7.8, 7.11 and 7.12).

FIGURE 12-TYPICAL TYPE B PACKAGES

The following are descriptions for the Figure 12 illustrations on the next page. These illustrations display several Typical Type B Packages. Type B Packages cover a wide range of physical size, from small radiographic devices to large waste casks and spent nuclear fuel casks.

- A) **BUSS Cask** (with impact limiters) Dimensions: 2.2 m O.D. by 2.7 m; Weight: 13,600 kg; Contents: Cs-137 (special form), 31 PBq (0.85 million Ci).
- B) **Industrial Radiography Exposure Device** (cutaway shows "S" tube for source in the shielding material) Dimensions: 33 cm by 20 cm by 13 cm; Weight: 21 kg; Content : Ir-192 (special form), 4 TBq (100 Ci).
- C) **Normal Form Material** (20WC-2) Dimensions: 0.6 m O.D. by 0.7 m; Weight: 200 kg; Content: Mo-99, 40 TBq (1,000 Ci), I-131, 7 TBq (200 Ci).
- D) **Multiple Special Form Sources** (drawing shows cutaway of metal cage for thermal protection of personnel and the shielded container with cooling fins) Dimensions: cage 50 cm cube: cask (without cooling fins) 20 cm O.D. by 28 cm; Weight: 186 kg; Contents: Ir-192, 400 TBq (10,000 Ci).
- E) **DOT Specification 6 M** (With flanged, leak-testable 2R inner container) Dimensions: 60 cm O.D. by 90 cm; Weight: 290 kg; Content: (special or normal form) many non-fissile radionuclides in solid form. Activity GBq to TBq quantities (10 mCi to 1,000 Ci), thermal output less than 10 watts.
- F) **Liquid Form Package** (Details of inner multiple containment and shielding not shown) Dimensions: Outer Steel Drum 49 cm O.D. by 52 cm; Weight 140 kg; Contents: Mo-99, I-131, Y-90 or Sr-90, 20 TBq to 55 TBq (500 to 1500 Ci).

FIGURE 12-TYPICAL TYPE B PACKAGES



Figure A-Buss Cask

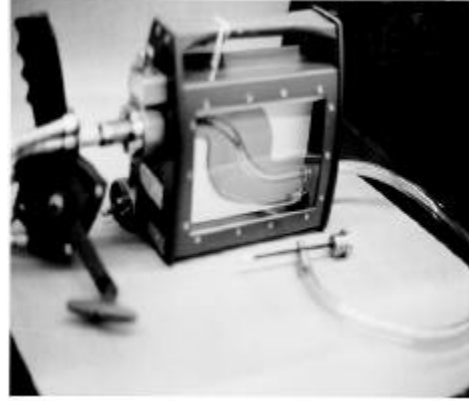


Figure B-Industrial Radiography Exposure Device

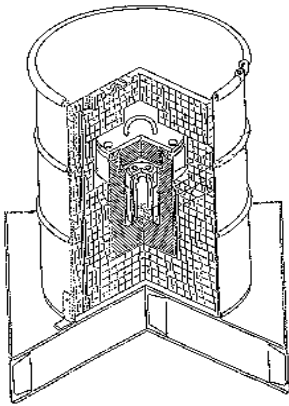


Figure C-Normal Form Material

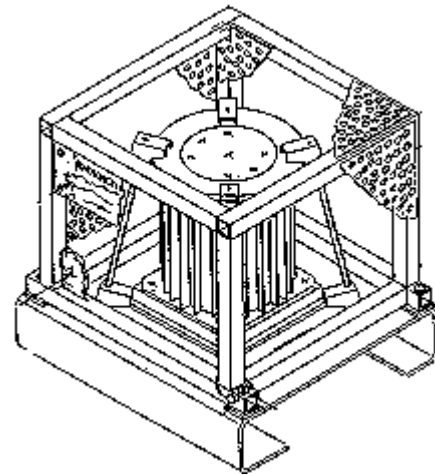


Figure D-Multiple Special Form Sources

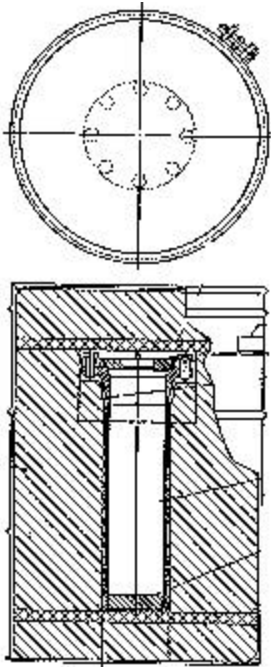


Figure E-DOT Specification

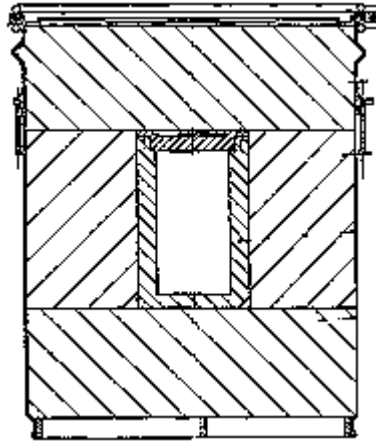


Figure F-Liquid Form Package 6M

2. Authorized Type B Packages-Domestic Use

Except for a few DOT Specification Type B packages described in 49 CFR 178, such as the DOT-6M and the DOT-20WC (see also 10 CFR §71.14) the vast majority of other authorized Type B packages are designs certified by NRC. Each design is approved under a NRC Certificate of Compliance and General License issued pursuant to 10 CFR 71.12. The DOT authorization for use of NRC approved Type B packages is provided in §173.416(a) and the standard requirements applicable to their use are in §173.471. In addition, numerous Type B packages in current usage are those approved by the U.S. Department of Energy (DOE) pursuant to the authority provided by DOT in §173.7(d). Many of these DOE-certified packages are also certified by NRC.

A useful reference for Type B NRC-certified packages is NRC Report, NUREG-0383.²² Updated annually, it is published in a three volume set which includes: a list of authorized users who have registered with NRC; actual copies of each current Certificate of Compliance; and a registry of NRC-Certified Quality Assurance Programs which have been issued pursuant to §10 CFR 71, Subpart H.

3. Foreign-Made Type B Packages

Type B Packages of foreign-origin which meet the applicable requirements of SS6-85 (1990), or 1973 as amended, and for which the foreign competent authority certificate has been revalidated by DOT pursuant to §173.473 (see also 10 CFR 71.16) are authorized only for export shipments from, import shipments

into, and shipments traveling through the U.S. For purely domestic shipments of such packages, NRC Certification of the package must be obtained.

F. INDUSTRIAL PACKAGING (IP-1, IP-2, AND IP-3)

On September 28, 1995, RSPA published a final rule (Docket HM-169A) ⁶³ which added the new category "Industrial Packaging" (IP) to the HMR. IP's are used in certain shipments of LSA materials and SCO's (see Section VI) which are usually categorized as nuclear waste. Three categories were established, IP-1, IP-2 and IP-3. The requirements for each IP category are in §173.411 and are summarized below:

- IP-1 Each IP-1 must meet the general design requirements prescribed in paragraph B. Except for this specific requirement, IP-1 packaging is essentially equivalent to the former "strong tight packaging" previously approved in 49 CFR for excepted packages and LSA materials.
NOTE: Strong tight packaging is still authorized by §173.427(b)(3) for exclusive-use shipments of some LSA materials and SCO material with package activity not exceeding the A₂ value, and by §173.427(c)(1) for exclusive use shipments of solid LSA-I and SCO-I in bulk packagings.
- IP-2 Each IP-2 must meet the general design requirements of an IP-1 and, when subjected to the free drop and stacking (compressive load) tests specified in §173.465(c) and (d) or evaluated against these tests by any of the authorized methods of §173.461(a), must prevent:
 - loss or dispersal of the radioactive contents, and;
 - any significant increase in the radiation levels recorded or calculated at the external surfaces for the condition before the test.
- IP-3 Each IP-3 must meet the requirements of an IP-1 and IP-2 and must additionally meet the requirements specified in §173.412(a)-(j).

G. FISSILE RADIOACTIVE MATERIAL PACKAGES AND SHIPMENTS

As defined in §173.403, **fissile material** is defined as plutonium-238, plutonium-239, plutonium-241, uranium-233, uranium-235 or any combination of these radionuclides. Unirradiated natural uranium and depleted uranium, and natural uranium or depleted uranium that has been irradiated in thermal reactors, are **NOT** included in this definition. Additional exceptions are provided in §173.453. All of these nuclides can fission, but in some cases, classification, shipping names, and packaging may be other than fissile.

In addition to considerations for radioactive content (radiological safety), a shipper of fissile radioactive material must also take into account certain other requirements to insure against accidental nuclear criticality (nuclear safety). Most packagings for fissile radioactive material are either fissile Type A or fissile Type B, with very rare exceptions; occasionally it may be possible to ship fissile material in an industrial package. For instance, unirradiated low-enriched uranium fuel assemblies have low radioactivity content and may be shipped in Type A packaging which requires little shielding, whereas irradiated spent fuel assemblies have very high radioactivity content and must be shipped in heavily shielded Type B casks.

Figure 13-Fissile Radioactive Material Packaging

The following are descriptions for the Figure 13 illustrations on the next two pages. These illustrations display some typical packages used in the transportation of fissile radioactive material. The descriptions of the illustrated packages show approximations of the dimensions, weight, and contents of the packages.

- A) **Type A Drum for UO₂** (Shows outer drum, solid insulation, sealed container, and inner receptacles for powder or pellets) Dimensions: 0.6 m O.D. by 0.7 m; Weight: 210 kg; Content: 30 kg UO₂ enriched up to 5% U-235, 3 GBq (0.08 Ci).
- B) **Power Reactor Fresh Fuel** Dimensions: 1.1 m O.D.by 5.5 m; Weight: 1,400 kg; Contents: 2 PWR fuel assemblies (2% of assemblies in a PWR), total 750 kg uranium as oxide (enriched to 4% U-235), 0.7 TBq (20 Ci).
- C) **Power Reactor Spent Fuel** (Shown with personnel barrier, on rail car) Dimensions: 1.6 m O.D. by 5.3 m; Weight: 64,000 kg; Contents: 7 PWR assemblies, (minimum cool time 120 days), (maximum thermal output 1,700 watts), fission products and other nuclides, 120 PBq (3.1 million Ci).
- D) **Uranium Hexafluoride (UF₆) Overpack** (Bare 30" Cylinder for UF₆ beside overpack) Dimensions: 1.1 m O.D. by 2.3 m; Weight: 3,700 kg; Contents: 2,200 kg UF₆ enriched to 5% U-235, 0.2 TBq (6 Ci).
- E) **Research Reactor Spent Fuel** (with impact limiters) Dimensions: 1.8 m O.D. by 3.3 m; Weight: 15,200 kg; Content: 7 kg U-235 (pre-irradiation), mixed fission products, 600 TBq (16,000 Ci).
- F) **Research Reactor Fresh Fuel** Dimensions: 0.8 m O.D by 1.2 m; Weight: 480 kg; Contents: 1 fuel element, uranium enriched to 95% U-235, 6.9 kg of U-235, 0.02 TBq (0.6 Ci).

Figure 13-FISSILE RADIOACTIVE MATERIAL PACKAGING

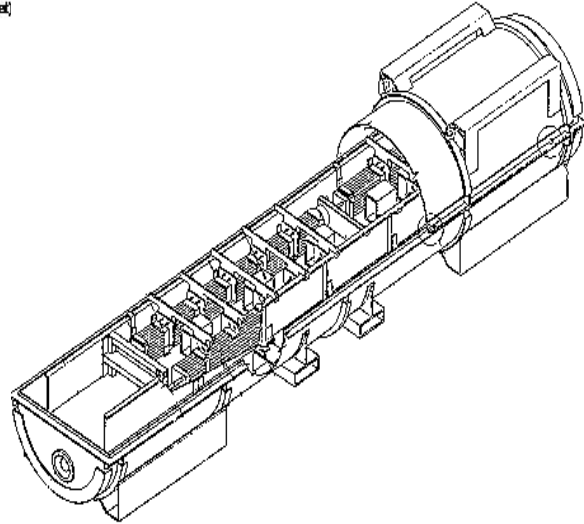
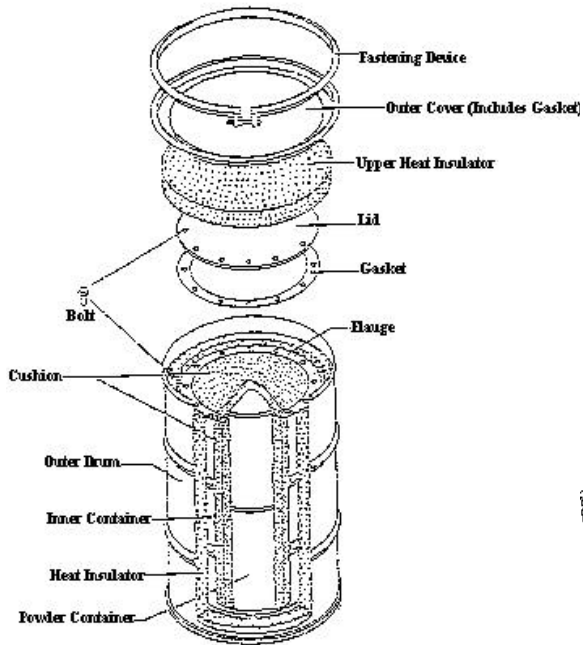


Figure A-Type A Drum for UO₂

Figure B-Power Reactor Fresh Fuel



Figure C-Power Reactor Spent Fuel with Personnel Barrier

Figure D-Uranium Hexafluoride (UF₆) Overpack and Bare 30" Cylinder

Figure 13-FISSILE RADIOACTIVE MATERIAL PACKAGING CONT'D

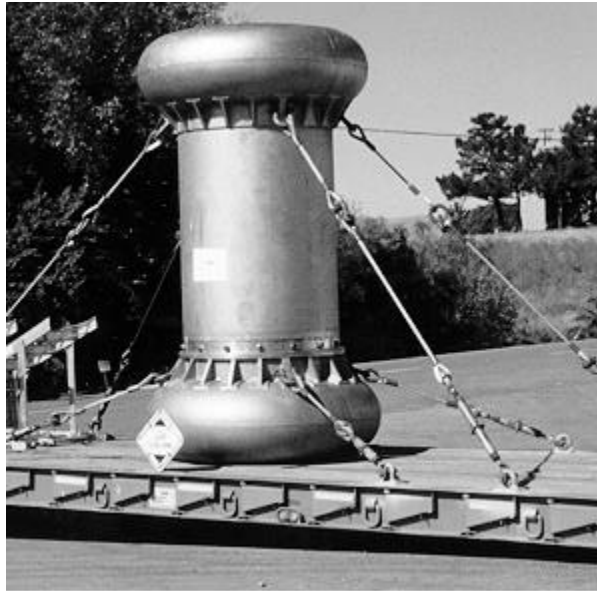


Figure E-Research Reactor Spent Fuel

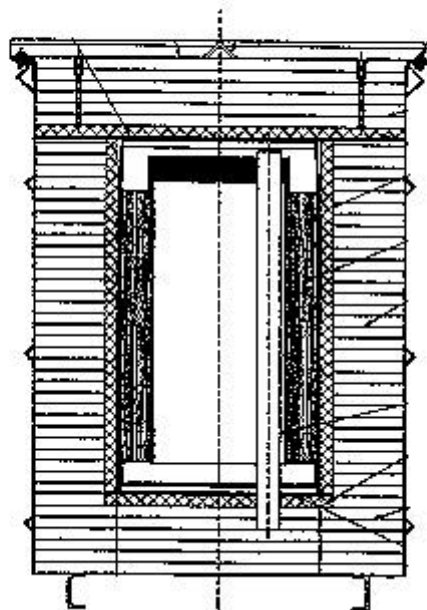


Figure F-Research Reactor Fresh Fuel

Except for several DOT specification packagings, e.g., DOT-6M, DOT-6L, DOT-20PF, DOT-21PF, all other Type A and Type B fissile packagings in use have been certified by NRC as indicated in §173.417(a)(4) and (b)(3) or by DOE, pursuant to the authority of §173.7(d). Fissile packages of foreign origin are subject to the same DOT requirements

as non-fissile Type B packages, and must be revalidated by DOT before they can be used for import/export of shipments.

NOTE: The packaging and shipment of fissile and non-fissile uranium hexafluoride (UF₆) are discussed in Section IX F.

RSPA's final rule Docket HM-169A eliminated the three fissile classes (Fissile Class I, II and III). Administrative control of all packages during transport is now based on the TI and the 50 TI/vehicle limit. However, for those fissile packages previously designated as Fissile Class III which were limited to a specified number of packages per vehicle, a new term "Fissile material, controlled shipment" has been developed which means

"...any shipment that contains one or more packages that have been assigned nuclear criticality control transport indices greater than 10 in accordance with §173.457".

For a "fissile material, controlled shipment", shippers are required to prepare and arrange for shipment under exclusive use controls as the primary means of administrative control to preclude co-mingling of fissile shipments and prevent accidental criticality during transportation.

VI. LSA AND SCO SHIPMENTS

A. BACKGROUND

Historically, the transportation category of Low Specific Activity (LSA) has been one of the most frequently misunderstood areas of DOT/NRC regulations. With the HM-169A⁶⁴ and 10 CFR 71 amendments of September 28, 1995, a previous inconsistency in the LSA requirements of the two agencies has been eliminated. LSA has been redefined, and grouped into three categories, LSA-I, LSA-II and LSA-III. A new or "sister" category, similar to LSA, has also been defined, and is termed "Surface Contaminated Objects" or "SCO", and is grouped into two categories, SCO-I and SCO-II.

LSA and SCO are extremely important radioactive material classifications with respect to shipments of low-to-medium level radioactive waste materials. The majority of shipments of such wastes originating from the nuclear fuel cycle facilities, and from all kinds of industrial, medical, research and academic communities are in the form of varying types of LSA materials. The new SCO category addresses solid wastes generated in the form of nonradioactive contaminated materials originating from cleanup, remediation and decontamination activities.

B. DEFINITION OF LSA

All LSA materials have a characteristic of presenting limited radiation hazard, because of their relatively low concentration of radioactivity. The specific activity, in units of Bq/g (or Ci/g), are generally lowest in LSA-I and highest in LSA-III. When the specific activity of an LSA material is computed, the radioactivity is divided by the mass of material in which the radioactivity is distributed; the mass of the packaging that may

surround the LSA is excluded from the calculation. The detailed description of the characteristics and limits for LSA-I, LSA-II, and LSA-III are indicated in §173.403 and 10 CFR 71.4, and they are unique for each LSA category. The definitions have been reproduced below:

LSA-I:

- ores containing only naturally occurring radionuclides, e.g., uranium, thorium, and uranium or thorium concentrates of such ores; or
- solid unirradiated natural uranium or depleted uranium or natural thorium or their solid or liquid compounds or mixtures; or
- radioactive material, other than fissile material, for which the A_2 value is unlimited; or
- mill tailings, contaminated earth, concrete, rubble, other debris, and activated material in which the radioactive material is essentially uniformly distributed and the average specific activity does not exceed $10^{-6}A_2/g$.

LSA-II:

- water with tritium concentration up to 0.8 TBq/liter (20.0 Ci/liter); or
- material in which the radioactive material is distributed throughout and the average specific activity does not exceed $10^{-4}A_2/g$ for solids and gases, and $10^{-5}A_2/g$ for liquids.

LSA-III:

- Solids, e.g., consolidated wastes and activated materials, that meet the leach test requirements of §173.468 and for which:
 - (i) the radioactive material is distributed throughout a solid or a collection of solid objects, or is essentially uniformly distributed in a solid compact binding agent, such as, concrete, bitumen, ceramic, etc.; and
 - (ii) the radioactive material is relatively insoluble, or it is intrinsically contained in a relatively insoluble material, so that, even under loss of packaging, the loss of radioactive material per package by leaching when placed in water for seven days would not exceed $0.1 A_2$; and
 - (iii) the average specific activity of the solid does not exceed $2 \times 10^{-3}A_2/g$.

C. DEFINITION OF SCO

Prior to Docket HM-169A, nonradioactive objects with contamination on their surfaces were regulated as LSA if the activity per square centimeter was within certain limits. The new regulations expanded the provisions for these materials and provided for their transportation as either SCO-I or SCO-II. The SCO-I and SCO-II contamination limits address both fixed and non-fixed contamination on both accessible surfaces and surfaces that are not accessible.

The contamination limits for SCO's as defined in §173.403 are illustrated in Table 9.

Table 9 - Contamination Limits for SCOs

Surface and Contamination Type	Limits in Bq/cm ²		Limits in μCi/cm ²	
	SCO-I	SCO-II	SCO-I	SCO-II
Accessible				
Non-fixed, most a	0.4	40	10 ⁻⁵	10 ⁻³
Non-fixed, β, γ, low-toxicity a	4.0	400	10 ⁻⁴	10 ⁻²
Fixed, most a	4 x 10 ³	8 x 10 ⁴	0.1	2.0
Fixed, β, γ, low-toxicity a	4 x 10 ⁴	8 x 10 ⁵	1.0	20
Inaccessible				
Fixed + non-fixed, most a	4 x 10 ³	8 x 10 ⁴	0.1	2.0
Fixed + non-fixed, β, γ, low-toxicity a	4 x 10 ⁴	8 x 10 ⁵	1.0	20

SCO-II limits exceed SCO-I limits by a factor of twenty, for all SCO's, except for the most common SCO, non-fixed contamination on accessible surfaces of objects, in which case, for both categories of radioactivity, the SCO-II limits exceed SCO-I by a factor of 100. The limits for all other surfaces, those that include fixed contamination, are 20 times higher for SCO-II than for SCO-I. For both SCO-I and SCO-II, the beta, gamma and low-toxicity alpha limits are a factor of ten greater than the limits for other alpha contamination. For inaccessible surfaces of both SCO-I and SCO-II, the total fixed plus non-fixed contamination limits are the same as the fixed contamination limits on accessible surfaces of both SCO-I and SCO-II for the two categories of radioactivity.

Problems in determining the proper classification for an object with surface contamination may involve methods of measuring the non-fixed and fixed contamination and determining whether the surfaces should be considered accessible or inaccessible. Although the IAEA has provided earlier guidance^{14c} the DOT and the NRC recognize that the implementation of the new LSA and SCO requirements needed guidance to facilitate compliance. Industry had expressed concern and provided excellent input to a guidance document published jointly by the NRC and DOT⁶². That document not only provides information related to the problems with measurements, calculations, and surface types mentioned here, but also treats other subjects such as packaging.

D. RADIATION LEVEL LIMIT FOR UNSHIELDED LSA/SCO MATERIALS

§173.427(a) imposes a very important additional condition for LSA and SCO which is based on the limitation of paragraph 421 of SS6-85 (1990)^{14a}. Simply stated, the quantity of LSA and SCO material in a single authorized package must be so restricted that the external radiation level from the unshielded material would not exceed 10 mSv/h (1 rem/h) at 3 meters.

This radiation dose rate limit restricts the permitted quantity of LSA and SCO materials in one package to the same external radiation hazard that is used for A₁ and A₂ values that apply to radioactive material that are not LSA or SCO. Essentially, the external

radiation from unshielded LSA or SCO from one package will not exceed the dose rate that would result from a special form source if released from a Type A package.

Compliance with this requirement is **not** possible by simply adding shielding to the packaging. The inherent property of the material must be so limited that even without any shielding, the dose rate would not exceed the limit of 1 rem/h at three meters. If it does, the material may no longer be considered LSA or SCO, and will require type B packaging. Shippers of LSA and SCO material will find useful information in determining activity, and unshielded radiation dose rates in the guidance document⁶².

E. AUTHORIZED LSA/SCO PACKAGING

DOT regulations authorize the following packages for shipment of LSA and SCO materials:

1. For domestic transportation only, strong tight packaging [§173.427(b)(3)] when transported in an exclusive-use vehicle, not exceeding an A₂ quantity in each packaging.

NOTE: There are no specific performance requirements for the “strong tight” packaging, but it must meet the “General Design Requirements” of §§173.410 and 173.24.

2. For domestic transportation only, in DOT-7A Type A packaging [§§173.427(b)(2), 173.412 and 178.350], except that the requirements of §§173.412(a), (b), (c), and (k) do not apply.
3. The former "NRC certified Greater Than Type A Packages":
These packagings include designs listed in NUREG-0383²² which had been previously certified and approved by NRC for greater than Type A, i.e., Type B, quantities of LSA material. After April 1, 1999, these packagings will no longer be authorized for LSA and SCO with unshielded contents having dose rates that exceed 10 mSv/hr (1 rem/hr) at 3 meters. If these packagings are certified by the shipper as IP-2 or IP-3 packagings, they may be used for transport of LSA and SCO that satisfy the 10 mSv/hr (1 rem/hr) at 3 m radiation level limit.
4. IP-1, IP-2, and IP-3 packaging and their use:
The category of industrial packages that is required for LSA or SCO materials is related to the potential radiological hazard of the material to be transported. LSA II and LSA III materials with radiological hazards greater than LSA I materials, require the more durable IP-2 and IP-3 packagings; while the LSA I material with lower radiological risk can be shipped in the lower durability IP-I packaging. This illustrates the general principle that contents posing greater radiological risk are required to be transported in more durable packages. Radioactive materials in liquid form generally present greater radiological risks than materials in solid form, if released from their package; therefore, LSA material in liquid form requires more durable IP packaging than solid LSA material. Similarly, non-exclusive use shipments do not have the controls during transport that may exist

for exclusive use shipments; thus nonexclusive use LSA requires packagings of a greater integrity than are required for exclusive use shipments. The categories of IP packages required for different LSA and SCO materials shipped under different transportation conditions are illustrated in the following Table 10 (appears as Table 8 in §173.427).

TABLE 10 INDUSTRIAL PACKAGE TYPES REQUIRED FOR LSA AND SCO SHIPMENTS
(49 CFR 173.427; Table 8)

Contents	Industrial packaging type	
	Exclusive use shipment	Non-exclusive use shipment
LSA-I:		
Solid.....	IP-1	IP-1
Liquid.....	IP-1	IP-2
LSA-II:		
Solid.....	IP-2	IP-2
Liquid and gas.....	IP-2	IP-3
LSA-III.....	IP-2	IP-3
SCO-I.....	IP-1	IP-1
SCO-II.....	IP-2	IP-2

5. Any Type B, B(U), or B(M) package authorized in §173.416.

Type B packages are usually used for materials other than LSA and SCO. However, they may be used if the radioactivity and physical form of the LSA or SCO to be shipped are such that it can be considered one of the authorized contents for a particular Type B package. For DOT specification Type B packages, the authorized materials are described as stated in §173.416, and for NRC certified Type B packages the authorized contents are described in the NRC certificate for each package.

FIGURE 14-TYPICAL PACKAGES FOR RADIOACTIVE WASTE

The following are descriptions for the Figure 14 illustrations on the next page. Some of these are appropriate for wastes classified as LSA or SCO. Others are for wastes that may be classified as Type B and/or fissile radioactive material. The packages illustrated and the dimensions and activities indicated are typical of packages in transportation.

- (A) **Intermodal Container** - Depending on contents or other packaging, it may be a conveyance, bulk packaging, strong tight or IP packaging; Dimensions: 2.4 m by 2.6 m by 6 m or 12 m; Weight: 18,000 kg; Contents: Type B or Type A packages, IP or strong tight packages, unpackaged LSA-1 or LSA-2 materials, SCO's unpackaged or in intermediate packagings. Radionuclides: non-fissile, fissile excepted, or fissile materials in quantities from limited quantities through Highway Route Controlled Quantities (HRCQ).
- (B) **TRUPACT-II** - Dimensions: 1.9 m O.D. by 1.9 m. Weight: 8,740 kg. Contents: Non-fissile, and fissile transuranic radionuclides dispersed in processed solid waste inside drums or other containers. Activity and fissile content is restricted for both inner container and total package; it is typically in the GBq to TBq range.
- (C) **Shielded LSA Cask** - Type A, IP-II and IP-III. Dimensions: 1.9 m O.D. by 2.2 m. Weight: 26,500 kg. Content: Irradiated solids, dewatered resins, and other solids meeting LSA and SCO definition. Non-fissile or fissile excepted radionuclides in quantities less than or greater than A_2 that meet the 10 mSv/h (1 rem/h) at 1 meter limit.
- (D) **Steel Drum** - Depending on content and inner packaging may be strong tight, Type A, Type B, or IP-I, II, or III. Dimensions: 0.7 m O.D. by 0.9 m; Weight: 290 kg; Contents: May range from limited quantities, LSA-I, II, and III, and SCO's I and II to Type B quantities. Radionuclides may be non-fissile, fissile excepted or occasionally fissile in quantities from MBq to TBq (mCi to 1000 Ci).
- (E) **Metal Box** - Strong tight, Type A, or IP. Dimensions 0.9 m by 1.2 m by 2.4 m; Weight: 3,600 kg; Content: LSA-I, II, or III, SCO's, or Radioactive Material n.o.s. Radionuclides may be non-fissile or fissile excepted in quantities from MBq to TBq (mCi to 1000 Ci).
- (F) **Wooden Box** - Strong tight, Type A, or IP. Dimensions vary widely; Weight ranges from 10 kg to 225 kg; Contents: Solid LSA's and SCO's, radionuclides, usually non-fissile, in quantities from MBq to TBq (mCi to 10 Ci).

FIGURE 14-TYPICAL PACKAGES FOR RADIOACTIVE WASTE

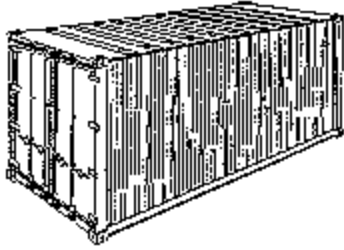


Figure A-Intermodal Container



Figure B-TRUPACT-II



Figure C-Shielded LSA Cask



Figure D-Steel Drum

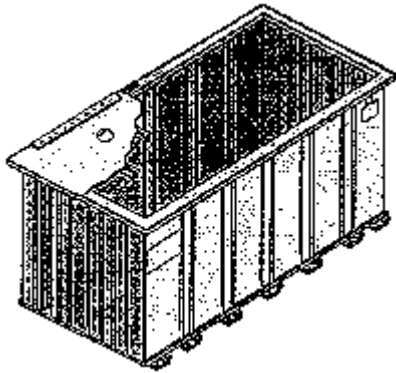


Figure E-Metal Box

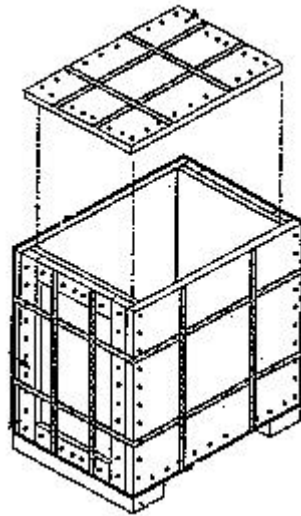


Figure F-Wooden Box

F. CONVEYANCE ACTIVITY LIMITS FOR LSA/SCO

The regulations that became effective on April 1, 1996⁶³, added restrictions concerning the total activity of some LSA and all SCO materials transported in a conveyance. An activity restriction of 100 A₂ per conveyance applies to all SCO's and to LSA II and LSA III materials that are combustible solids, or are in liquid or gaseous form. Shippers will find some guidance in the LSA/SCO document developed by DOT and NRC⁶².

**TABLE 11
CONVEYANCE ACTIVITY LIMITS FOR LSA AND SCO
(See §173.427, Table 9)**

Nature of material	Activity limit for conveyances
LSA-I.....	No limit.
LSA-II and LSA-III; noncombustible solids.	No limit.
LSA-II and LSA-III; combustible solids and all liquids and gases.	100 A ₂
SCO.....	100 A ₂

VII. 49 CFR PART 172 HAZMAT COMMUNICATIONS AND RELATED REQUIREMENTS

A. General

Shippers have the greatest responsibility for compliance with the communication requirements of Part 172 of 49 CFR, but carriers are also subject to some of the requirements. Safe transportation of radioactive material requires correct communication

of the specific hazards of the materials. Generally, an essential part of the total system for providing safety in transport of radioactive material is the requirement for communication of information on the specific hazards of the materials. The communication requirements of 49 CFR Part 172 are designed to complement the basic safety requirements for package activity limitation and package integrity. Historically, Part 172 has addressed the conventional communication requirements, such as, proper shipping papers, package marking, package labeling, and vehicle placarding. In recent years, additional subparts have been added to Part 172 to address emergency response information and hazmat employee training.

B. §172.101 List of Hazardous Materials and Proper Shipping Names for Radioactive Materials (Subpart A & B)

Subpart A of Part 172 describes the applicability of the regulations to shippers and carriers. Subpart B contains the hazardous materials table. The Hazardous Materials Table (HMT) in §172.101 classifies those materials which DOT has designated as hazardous materials for purposes of transportation. The HMT prescribes the requirements for shipping papers, marking, labeling and transport vehicle placarding applicable to the shipment and transportation of those hazardous materials. For each listed material, the table identifies the hazard class, the UN identification number, and gives the proper shipping name or directs the user to the proper shipping name. In addition, the HMT specifies or references other regulatory requirements pertaining to labeling, packaging, quantity limits aboard aircraft and stowage of hazardous materials aboard vessels.

Before using the HMT, shippers should be familiar with the ground rules which explain the information in the ten columns of the table, and the explanatory symbols [see §§172.101(a)-(l) that precede the HMT]. The information in the paragraphs preceding the HMT, provides extensive information related to the proper use of the table and the information in the table.

The most commonly used proper shipping names for radioactive material are listed in Table 12. The proper shipping names for less frequently encountered radioactive material, all of which are of a comparatively low order of radioactivity, but have a secondary hazard, are listed in Table 13.

The proper shipping name to be used for some radioactive material is not always obvious. Selecting the most appropriate name is the intent of the requirement of §172.101(c)(11).

TABLE 12
MOST COMMONLY USED PROPER SHIPPING NAMES FOR RADIOACTIVE
MATERIAL
(49 CFR 172.101)

Radioactive material, excepted package-articles manufactured from natural uranium <u>or</u> depleted uranium <u>or</u> natural thorium -- UN 2910
Radioactive material, excepted package-empty package <u>or</u> empty packaging -- UN 2910
Radioactive material, excepted package-instruments <u>or</u> articles -- UN 2910
Radioactive material, excepted package-limited quantity of material -- UN 2910
Radioactive material, surface contaminated object, n.o.s. <u>or</u> Radioactive material, SCO, n.o.s. -- UN 2913
Radioactive material, low specific activity, n.o.s. <u>or</u> Radioactive material, LSA, n.o.s. -- UN 2912
Radioactive material, special form, n.o.s. -- UN 2974
Radioactive material, fissile, n.o.s. -- UN 2918
Radioactive material, n.o.s. -- UN 2982

TABLE 13
LESS FREQUENTLY ENCOUNTERED PROPER SHIPPING NAMES FOR
RADIOACTIVE MATERIAL BY CHEMICAL NAME-MATERIALS HAVING A
SUBSIDIARY HAZARD
(From §172.101)

(All have a low hazard from radioactivity, but have a serious secondary hazard.)

Thorium metal, pyrophoric	UN 2975
Thorium nitrate, solid	UN 2976
Uranium metal, pyrophoric	UN 2979
Uranyl nitrate hexahydrate solution	UN 2980
Uranyl nitrate, solid	UN 2981
Uranium hexafluoride, fissile (<i>containing more than 1 % U-235</i>)	UN 2977
Uranium hexafluoride, fissile excepted <u>or</u> non-fissile	UN 2978

C. Shipping Paper Requirements (Subpart C, §§172.200-172.205)

As with other hazardous materials shipments, certain essential elements of information must be included on shipping papers. The availability of a complete and correct shipping

paper description for a hazardous material shipment is vital not only to the carrier and the consignee, but also to emergency response personnel in the event of an incident.

1. **Basic Shipping Paper Requirements** - The shipping paper description must basically include the following:

- a. The proper shipping name from §172.101;
- b. The UN hazard class or division - radioactive material is hazard class 7;
- c. The UN Identification number;
- d. The net quantity of material by weight or volume.

NOTE: For most radioactive material, it is not required to list the weight or volume, since the additional requirements of §172.203(d) provide better information, i.e., the radioactivity content in Becquerels (Curies). A listing of weight or volume is usually needed only with respect to establishing freight charges;

- e. The letters "RQ", if the shipment is a "hazardous substance" [see §172.101, Appendix A, Table 2 for RQ values of radionuclides].
- f. Emergency response telephone number as prescribed in Subpart G, Part 172.

A shipping paper may contain additional information concerning the material, provided it is not inconsistent with, and does not cause confusion with, the basic description. Unless otherwise specified, the additional information must be placed after the required basic description.

2. **Additional Shipping Paper Description** the shipping paper description for radioactive material must also include the following [§172.203(d)] (this information follows items (a), (b), and (c) above):

- a. The words "radioactive material", unless these words are contained in the proper shipping name;
- b. The name of each radionuclide in the material as listed in §173.435. For mixtures of radionuclides only the radionuclides that constitute 95% of the hazard of the mixture as described in §173.433(f) need be listed on shipping papers and package labels;
- c. A description of the physical and chemical form of the material, unless the material is "special form". A generic description of the material, such as, protein, carbohydrate, enzyme, etc., is authorized if the exact chemical form is difficult to specify;
- d. The activity contained in each package in the shipment in appropriate SI units, e.g., Becquerel, Terabecquerel, etc., or in terms of appropriate SI units followed by customary units, e.g., curies, millicuries, etc. Except for Pu-238, Pu-239 and Pu-241, the weight in grams or kilograms of fissile radionuclides

may be inserted instead of activity units. For Pu-238, Pu-239 and Pu-241, the weight in grams or kilograms may be inserted in addition to the activity units. If the package contains a "Highway Route Controlled Quantity", those words must also be shown with the basic description;

- e. The category of RADIOACTIVE label applied to each package in the shipment, for example "RADIOACTIVE-WHITE I";
 - f. The transport index assigned to each package in the shipment bearing a RADIOACTIVE-YELLOW II or RADIOACTIVE -YELLOW-III label;
 - g. For a shipment of fissile material, the additional information required in §172.203(d)(7), i.e., the words "Fissile Excepted", "Warning - Fissile material, controlled shipment," etc, as appropriate;
- NOTE:** For a package containing a fissile nuclide having an activity content less than the definition of "radioactive material" (70 Bq/g or 0.002 μ Ci/g), the term "Fissile Excepted" need not be added, since materials having activity content less than the transport definition of radioactive material are not subject to transportation regulations.
- h. For a shipment required to be consigned as exclusive use, an indication that the shipment is consigned as exclusive use, along with any appropriate special instructions to the carrier relative to maintenance of exclusive use shipment controls.
 - i. For a shipment of LSA or SCO materials, the appropriate group notation, e.g., LSA-I, SCO-II, etc.
 - j. The certificate identification marking required on the package must also be noted on the shipping papers if the package is one which is: (1) approved and certified by the NRC or DOE, or (2) is a package of foreign origin which has been revalidated by DOT.

3. Other Information and Examples of Shipping Papers Entries

As indicated above, a great deal of specific information is required on shipping papers for radioactive material. While there is no precise prescription for the shipping paper format, the first three entries must be in a specific order [see 1a-1c above].

NOTE: Regulations of international transport organizations such as ICAO and IMO specify only the content of shipping papers. However, the IATA tariff specifies both content and format.

Other descriptive information is allowed, such as the functional description of the product, or the applicable regulatory citation under which the shipment is offered. This additional description must not confuse or detract from the required

description. The following are some example entries of different ways shipments can be described on shipping papers:

Ex. 1: One (1) box, Radioactive material, special form, n.o.s., Class 7, UN 2974, RQ, Radiographic camera, Iridium - 192, 2.2 TBq. (60 Ci), Radioactive Yellow - II, 0.6 Transport Index, USA/9033/B(U), Cargo aircraft only. In emergency contact 1-800-000-0000.

NOTE: Physical and chemical form is not listed since material is "special form".

Ex. 2 One (1) carton, Radioactive material, n.o.s., Class 7, UN 2982, Cobalt-60, 1.1 GBq (30 mCi), liquid, cobalt in 50 ml 5% hydrochloric acid solution, transport index 1.8, Radioactive Yellow - III and CORROSIVE labels applied. In emergency contact 1-800-000-0000.

Ex. 3 One (1) box, Thorium nitrate, solid, Radioactive material, Class 7, UN 2976, 10 kg. Thorium natural, as powdered solid thorium nitrate, 48 MBq (1.3 mCi), Radioactive YELLOW-II and OXIDIZER labels applied, TI 0.1, Cargo aircraft only. In emergency contact: 1-800-000-0000.

NOTE: Since the material is specifically listed in §172.101, there is no "n.o.s." in the proper shipping name. Although this material is also an LSA-I, it must be packaged and shown on shipping papers in accordance with the specific packaging requirements of §173.419, with air shipment limited to not more than 15 kg. by cargo aircraft only.

Ex. 4 Three (3) drums, Radioactive material, LSA, n.o.s., Class 7, UN 2912, LSA-II, non-compacted solid debris and waste, Cs¹³⁷, Co⁶⁰ and Sr⁹⁰, solid as inorganic salts or elemental, 1.5, 0.57, and 0.18 MBq (0.04, 0.015 and 0.005 mCi), respectively. Drum Nos. 731, 680, and 541 are IP-1 packagings, Radioactive White-I labels [see attached Radwaste Manifest (NRC Form 540)]. Exclusive-use shipment instructions attached for more details. In emergency, contact (24-hour) 1-800-000-0000.

NOTE: This is an example of a shipment under 173.427(b)(1).

Ex. 5 Three (3) cartons, Radioactive material, n.o.s., Class 7, UN 2982, Material to be used in physical chemistry research project at University.

Carton No.1, catalytic specimen, S³⁵, 70 mCi, solid, powdered metal oxide matrix, Radioactive White - I label, 60 lbs.

Carton No.2, Tagged solvent, Cl^{30} , 3 mCi, liquid, nonflammable organic, Radioactive White - I label, 50 lbs.

Carton No. 3, converter element, Fe^{59} and Fe^{55} , 30 mCi and 20 mCi, solid, steel part, TI 1.6, Radioactive Yellow-III label, 80 lbs.

NOTE: This is an example of how one basic entry can be used along with three different packages. Detailed information is given on the content, labels, and TI of each package.

Ex. 6 Four (4) Packages, Uranium Hexafluoride, fissile, Class 7, UN 2977, radioactive material, Total Gross Wt. 18,795 kg (41,350 lb).

Solid Uranium Hexafluoride (UF_6) contained in four Model 30B steel cylinders, each enclosed in a Model UX-30 protective overpack. NRC Certificate USA/9196/AF, Type A.

Each cylinder contains 2277 kg (5020 lb) of UF_6 at 5.0 % U-235 enrichment or 63 kg (115 lb) U-235 (629 MBq.).

RADIOACTIVE YELLOW-III labels, TI=5.0/package.
RADIOACTIVE and CORROSIVE placards and orange "2977" UN panel applied.

24-hour emergency telephone no.: contact 1-888-888-8888.

4. Documentation for excepted packages - Packages shipped according to the exceptions provided in §§173.421, 173.424, 173.426 and 173.428 (for Limited Quantity, Instruments or Articles, Articles Manufactured from Natural or Depleted Uranium or Natural Thorium, and empty radioactive material packaging) are excepted from the detailed shipping paper description requirements.

Such excepted packages must, however have a certification statement or notice "in" or "on" the package or forwarded with the package. That notice must include the name of the consignor or consignee and a specific statement which is selected on the basis of the proper shipping name for the package. The following example illustrates such a notice on a shipping paper for an excepted package containing an instrument or article pursuant to §173.424:

One (1) carton, Ajax Model 123 Monitor, "This package conforms to the conditions and limitations specified in 49 CFR §173.424 for radioactive material, excepted package-instruments or articles, UN 2910."45 lbs.

NOTE: Although shipping papers are not required for these excepted packages, they are not forbidden. Furthermore, in accordance with §173.422(b)(3), a shipping paper is required if the radioactive material in the excepted package is also (or is part of) a hazardous substance or hazardous waste (as defined in §171.8). Additionally, when air shipment of excepted packages is involved,

shippers should be aware that a prescribed statement on an airbill, similar to those in the following paragraphs, is required by ICAO and IATA regulations.

5. Shipper's Certification (§172.204) - Unless excepted, a shipping paper must include a certification statement, signed by the person offering the package for transport. The certification must appear on the paper that lists the required shipping description.

The following statement listed in 49 CFR 172.204(a)(1) (or an alternate statement listed in §172.204(a)(2)) must be used for all hazardous materials shipments except for those by air:

"This is to certify that the above-named (or herein named) materials are properly classified, described, packaged, marked, and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation."

For air transportation, the following language may be included on shipping papers in place of the above statement:

"I hereby certify that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and in proper condition for carriage by air according to applicable national governmental regulations."

The requirements and limitations for carriage of radioactive materials aboard aircraft are prescribed in §175.75(a)(3) and 175.700 through 175.705. The following statement, with deletion marking, is required for all hazardous material (including radioactive material) shipments by air:

"This shipment is within the limitations for passenger carrying/cargo aircraft only (delete non-applicable)."

6. Proper Shipping Names for Fissile Materials

Shippers of fissile radionuclides are reminded of the specific requirements in §172.203(d)(7)(i). That section requires the addition of the words "fissile excepted" if the package contains a fissile radionuclide in such quantity or form that it is excepted from the specific requirements for fissile materials (§173.453). The following rules-of-thumb should be considered in selecting the correct proper shipping name for fissile radionuclides:

If the radioactive material is neither fissile excepted nor satisfies the conditions for shipment in an excepted package, use the shipping name: "Radioactive material, fissile n.o.s., UN 2918"; or

If a fissile excepted quantity is present and it also can be shipped in an excepted package, use the shipping name: "Radioactive material, excepted

package-limited quantity of material, UN 2910" and add the words "fissile excepted"; or

If the radioactive content does not satisfy the conditions for shipment in an excepted package, but the fissile content is excepted, use: "Radioactive material, n.o.s., UN 2982" and add the words: "fissile excepted"; or "Radioactive material LSA; n.o.s., UN 2912" or "Radioactive material, SCO, n.o.s., UN 2913"; or Radioactive material, special form, n.o.s., UN 2974, as appropriate.

D. MARKING REQUIREMENTS (SUBPART D)

1. **Basic Requirements** Certain basic elements of information (other than required labels discussed below) are required as "marking". When the marking is required, it is sometimes referred to as "specification" marking, although this term is usually used with reference to "specification packaging". The required markings on non-bulk radioactive material packagings are prescribed in §172.301 and include:
 - (a) The proper shipping name and UN Identification number for the materials as shown in §172.101;
 - (b) For exemption packagings, the words "DOT-E" followed by the applicable DOT exemption number assigned;
 - (c) The name and address of the consignor or consignee;
 - (d) "RQ", if a "hazardous substance" (See §172. 324(b)) and Table 2, §172.101, Appendix A).
2. **Liquid Marking Requirement** (§172.312)
Each non-bulk packaging containing a liquid within its inner containment vessel must be packed with that vessel closure upward and must be legibly marked with the package orientation marking which conforms to ISO Standard 780-1985. Such marking must be on two opposite sides with the double arrows in the symbol pointing in the correct upright direction. Arrows for any other purposes may not be displayed on a package containing a liquid hazardous material.
3. **Radioactive material** (§172.310)
Except for "excepted" packages each radioactive material package must also be marked with:
 - (a) Its gross weight if it exceeds 50 kg (110 lbs);
 - (b) "TYPE A" or "TYPE B", as applicable. This relates to the packaging design - not the radioactive content;
 - (c) The applicable DOT Specification number, NRC or DOE package certificate identification number, as specified in the DOT specification or relevant Certificate, e.g., "USA-DOT-7A", USA/9166/B(U)-85, etc.;

- (d) For certain Type B packages, the trefoil radiation symbol which conforms to the standard of Appendix B, §172;
- (e) "IP-1", "IP-2", or "IP-3" as applicable, when such packages contain LSA or SCO materials. (This marking is recommended, but not presently required nor prohibited by §172.303.)

4. Bulk Radioactive material Packages

Bulk packaging for a hazardous material is defined in §171.8. The concept of "bulk" packaging reflected in that definition is that the packaging may involve the vehicle itself, a freight container or other large closed receptacle in which the hazardous material is loaded with no intermediate form of containment. Bulk radioactive material packaging is therefore most likely to involve conveyances such as: closed tight truck/vans or rail cars containing contaminated soils and debris, low-level radioactive waste to be consolidated, or objects with internal and/or external contamination; large bins or freight containers for solids; or tanks containing slurries or other liquid wastes. For such shipments, the bulk packaging is required to be marked on its exterior with the applicable UN hazard identification number as specified in §172.101 [see §172.302]. When required for radioactive material, this identification number must be placed on an orange rectangular panel adjacent to the required RADIOACTIVE placard [see §172.332]. It may not be placed on the RADIOACTIVE placard in lieu of the word "RADIOACTIVE" for domestic shipments, according to §172.334(a). However, this prohibition does not exist in the international (IAEA and IMO) regulations.

E. LABELING REQUIREMENTS (SUBPART E)

Each package of Class 7 (radioactive material), unless excepted, must be labeled on two opposite sides, with a distinctive warning label. Each of the three label categories, i.e., "RADIOACTIVE WHITE-I", "RADIOACTIVE YELLOW-II", or "RADIOACTIVE YELLOW-III", bears the unique trefoil symbol for radiation as prescribed in §172, Appendix B, [see §172.403 and §172.436-440].

The RADIOACTIVE labels alert persons, particularly the handlers, that the package contains radioactive material and that the package **MAY** require special handling and stowage distance/separation control. As illustrated in Figure 15, a label with an all white background color indicates that the external radiation level is low and no special stowage controls or handling are required. If the upper half of the label is yellow, the package will have an external radiation level or fissile (nuclear safety criticality) characteristic which requires consideration during stowage in transportation. If the package bears a yellow label with three red stripes, the transport vehicle must be placarded RADIOACTIVE by the carrier when the packages are accepted from a shipper. Placarding is discussed in more detail below.

FIGURE 15 PACKAGE LABELS



For all labels, vertical bars on each label are in red. Each label is diamond-shaped, four inches (10 cm) on each side, and has a black solid-line border one-fourth inch from the edge. The background color of the upper half (within the black line) is white for the "I" label. It is yellow for the "II" and "III" labels. The regulatory provisions of §§172.403(f) and (g) that apply to the use of these labels are indicated below.

The following applicable items of information must be entered on the blank spaces of each label by legible printing (manual or mechanical) using a durable, weather-resistant means of marking:

"Contents" - The name of the radionuclides as taken from the listing in §173.435 (Established radiation protection symbols are authorized). For mixtures of radionuclides, with consideration of space on the labels, list the radionuclides that represent 95% of the hazard present as determined by §173.433(f).

"Activity" - Activity must be expressed in appropriate SI units, e.g., Becquerel (Bq), terabecquerels (TBq), etc., followed optionally by insertion of appropriate customary units (Curies (Ci), millicuries (mCi), microcuries (μ Ci), etc.) in brackets.

"Transport Index" - [see §172.403 for determining the TI].

The **principal** criteria which the shipper must consider in choosing the appropriate category of label are the dose rate at the surface of the package and the TI. [see Table 14].

TABLE 14**LABEL CATEGORY BASED ON TI AND SURFACE RADIATION LEVEL**

Transport Index	Maximum radiation Level at any point on the external surface	Label Category ¹
0 ²	Not more than 0.005 mSv/h (0.5 mrem/h)	White – I
More than 0 but not more than 1	More than 0.005 mSv/h (0.5 mrem/h) but not more than 0.5 mSv/h (50 mrem/h)	Yellow – II
More than 1 but not more than 10	More than 0.5 mSv/h (50 mrem/h) but not more than 2 mSv/h (200 mrem/h)	Yellow – III
More than 10	More than 2 mSv/h (200 mrem/h) but not more than 10 mSv/h (1,000 mrem/h)	Yellow – III (Must be shipped under exclusive use provisions; see §173.441(b).)

¹Any package containing a “highway route controlled quantity” (§173.403) must be labeled as RADIOACTIVE YELLOW - III. ²If the measured TI is not greater than 0.05, the value may be considered to be zero.

F. PLACARDING REQUIREMENTS (SUBPART F)1. Placarding by Carrier

A carrier is required to placard the transport vehicle (rail or highway) if any radioactive material package bears the "RADIOACTIVE YELLOW-III" label (§172.440) or if the shipment includes LSA or SCO material required by §173.427 to be consigned as exclusive use (§172.504). The RADIOACTIVE placard is illustrated in Figure 16 (§172.556).

**FIGURE 16
VEHICLE PLACARD**



The background color for the black trefoil symbol in the upper half of this 12" by 12" placard is yellow.

NOTE: In the case of foreign shipments coming into the U.S., the placard may take the format of an enlarged RADIOACTIVE label.

2. Placarding By the Shipper

PLACARDING FOR EXCLUSIVE-USE SHIPMENTS OF LSA AND SCO

Pursuant to the shipper requirements of §173.427(a)(6)(v), except for shipments of unconcentrated uranium or thorium ores, the transport vehicle must be placarded by the shipper with the RADIOACTIVE placard. This requirement differs from the customary placarding requirement wherein the carrier must placard on the basis of any RADIOACTIVE YELLOW-III packages being present. **LSA or SCO packages consigned as exclusive use (domestic shipment only) are excepted from labeling requirements.** Therefore it would be illogical to base the requirement for placarding of exclusive use shipments of LSA and SCO on the presence of YELLOW-III labels.

G. EMERGENCY RESPONSE INFORMATION REQUIREMENTS (SUBPART G)

1. Applicability 49 CFR Part 172, Subpart G, §172.600⁵⁸ requires shippers to provide emergency response information on hazardous materials shipments. The regulation applies to any shipment of a hazardous material which is required to have shipping

papers. Shipments of excepted radioactive material packages (packages containing limited quantities, instruments or articles, or “Empty” packagings) are excepted from shipping paper requirements, and, therefore, are not subject to the emergency response information requirements.

2. Specific Requirements

- (a) §172.602 - At a minimum, the emergency response information must provide: the basic description and technical name of the hazardous material, immediate hazards to health, immediate precautions to be taken in the event of an accident or incident, immediate methods for handling fires, immediate methods for handling spills or leaks in the absence of fire, and preliminary first aid measures.

This information must be on a shipping paper or an associated document and kept on the vehicle and maintained at all locations where the shipment is handled. This required information is very similar to the information in the guide pages of the North American Emergency Response Guidebook^{19f} (NAERG). In many cases, shippers satisfy this requirement by attaching to their shipping papers an appropriate guide page from the NAERG.

It should be recognized that there is a wide range of potential hazards for the many types of radioactive material that can be shipped under a given shipping name and guide number. If the product being shipped has properties that are either less hazardous or more hazardous than the description in the applicable guide in the NAERG, then the emergency actions could be more specific than those in the guide. In such cases, the shipper may wish to satisfy the technical information requirements from §172.602 (a)(1-7) by preparing statements that are appropriate to the product being shipped.

- (b) §172.604 - Shippers are required to provide an emergency response telephone number which must be monitored on a 24-hour basis while the shipment is in transportation. The number must be of a person or entity who is knowledgeable of mitigation information or has **immediate access** to such a person. The number may be of an agency which is capable of providing the information and agrees to do so.

3. NAERG

DOT, in partnership with Canada and Mexico, has developed and distributed the 1996 North American Emergency Response Guidebook-A Guidebook for First Responders During the Initial Phase of A Hazardous Materials/Dangerous Goods Incident^{19f} with the intent that a copy be in every emergency services vehicle in North America. The NAERG is used by first responders to a hazardous materials accident as a means of obtaining initial information on the identification and hazards of the specific material and to assist in decision-making on actions to be taken.

In using the NAERG, the four-digit UN hazard identification number which is assigned to each DOT proper shipping name is cross referenced to a three-digit guide number in the NAERG. For class 7 radioactive material, the NAERG contains guide numbers which correlate to all DOT proper shipping names for radioactive material. Although there will be changes in the proper shipping names and UN identification numbers with the adoption of ST-1 (see page 2), in the 1996 edition of the NAERG, the correspondence between guide numbers and UN identification numbers is as follows:

- 161- Used with UN 2910 (Excepted packages)
- 162- Used with UN 2912 and 2913 (LSA and SCO), and UN 2975, 2976, 2979, 2980 and 2981 (LSA oxidizers and pyrophorics).
- 163- Used with UN 2982 (Radioactive material, n.o.s.)
- 164- Used with UN 2974 (Radioactive material, special form)
- 165- Used with UN 2918 (Fissile radioactive material)
- 166- Used with UN 2977 and 2978 (Uranium hexafluoride, LSA and fissile)

H. TRAINING REQUIREMENTS (SUBPART H)

§§172.700-172.704 contain the requirements for training of "hazmat employees" involved in transportation of hazardous materials. Each "hazmat employer" must ensure that each hazmat employee receives the required training and testing in the following subjects:

- General awareness/familiarization with 49 CFR hazmat transportation requirements;
- Function-specific training; and
- Safety training.

Initial training is required within 90 days of employment on a specific job. The hazmat employee must have **recurrent training** every three years or within 90 days after assignment to a new job for which training has not already been provided.

(1) General Awareness/Familiarization Training

This requirement is directed toward the hazmat employee being able to recognize and identify hazardous materials in a manner consistent with the hazard communication standards of 49 CFR 172. Training in this area should include a basic orientation on DOT shipping papers, package marking, package labeling, emergency response information and vehicle placarding requirements. Testing should focus on awareness, recognition and identification.

(2) Function-Specific Training

The term "function-specific" is intended to focus the training on those hazardous material activities (functions) which actually involve the hazmat employee. If the employee does not perform certain hazmat activities, then neither training nor testing in those activities is required.

Note: A reference on the application of the Subpart H training requirements is the DOT pamphlet⁵⁴ entitled "TRAINING-Its The Law" which is updated periodically. A reference document on training requirements as they apply to nuclear power plant hazmat employees involved with radioactive material transportation is EPRI-TR-102662⁵⁵ "Guidance on New DOT Training Requirements for Hazardous Materials Employees". There are a series of Hazardous Materials Training Classes, developed by the RSPA Office of Hazardous Materials Initiatives and Training, that are excellent resources for training.

(3) Safety Training

Personal Safety
Emergency Response
Accident Avoidance

(4) Testing and Record keeping

Each hazmat employee must be trained and tested to determine the effectiveness of the training received. The hazmat employer must certify that each hazmat employee has been properly trained, and the hazmat employer must maintain the records thereof.

VIII. OVERVIEW OF NRC'S 10 CFR TRANSPORT-RELATED REQUIREMENTS

Transportation requirements of NRC which apply to transport of NRC-licensed radioactive material are located in §10 CFR 71. Since 10 CFR part 71 is a matter of "compatibility" for regulatory programs of the NRC "Agreement States", effectively it is also applicable to activities of Agreement State licensees. Several other transport-related requirements are also in 10 CFR Parts 20 and 61. A brief overview of these follows:

A. 10 CFR Part 71

In accordance with 10 CFR 71.5, each NRC licensee who transports licensed radioactive material outside the site of usage, as specified in the NRC license, or where transport is on a public highway, or who delivers licensed material to a carrier for transport, must comply with the applicable requirements of the DOT hazardous materials transport regulations. NRC inspects the radioactive material shipping practices of its licensees, and enforces licensee compliance with the DOT regulations.

In addition, with the exception of DOT specification packages and packages approved by the U.S. Department of Energy (DOE), all packages used for domestic shipments of

- non-LSA/SCO Type B quantities,
- LSA/SCO Type B quantities for which the unshielded radiation level at 3 meters is greater than 10 mSv/hour, and
- fissile material which exceeds a ?fissile exempt? quantity,

must be certified for use by the NRC. The user must register with the NRC and make all shipments in compliance with the terms of the package approval. The package approval standards and performance requirements are set out in 10 CFR 71.

Prior to the September 28, 1995, amendments, the NRC certified packages for LSA materials when contents exceeded A₂. After April 1, 1999, those packages may no longer be used for LSA material or SCO when the radiation dose rate from the unshielded material exceeds 10 mSv/hr (1 rem/hr) at 3 m.

B. 10 CFR PART 20

This Part has only two transportation-related requirements:

10 CFR 20.1906-This section requires that an NRC licensee who receives a radioactive package perform certain monitoring of the package, as follows:

1. Except for packages containing gaseous or special form radioactive material, any package bearing either of the three categories of RADIOACTIVE labels must be monitored for **external surface contamination**;
2. The external surface of any package containing greater than a Type A quantity, i.e., a Type B quantity, must be monitored upon receipt for **external radiation levels**;
3. Monitoring for both surface contamination and external radiation levels must be performed on any package known to contain radioactive material, **if there is evidence of degradation of package integrity**;
4. Instances of surface contamination and/or external radiation levels exceeding the applicable limits **must be reported to the appropriate NRC regional office**.

NOTE: NRC AND AGREEMENT STATES REGULATE LICENSED SHIPPERS AND RECEIVERS OF RADIOACTIVE MATERIAL PACKAGES. DOT'S AUTHORITY APPLIES TO SHIPPERS AND CARRIERS, NOT TO RECEIVERS.

§10 CFR 20.1601(c)-Control of access to High Radiation Areas containing radioactive material packages. This Section reads as follows:

"Control is not required for each entrance or access point to a room or other area that is a high radiation area solely because of the presence of radioactive material prepared for transport and labeled in accordance with the regulations of the Department of Transportation provided that:

- (1) The packages do not remain in the area longer than 3 days; and
- (2) The dose rate at one meter from the external surface of any package does not exceed 0.1 mSv (0.01 rem) per hour".

In implementing the provisions of §20.1601(c), it is apparent that time is of the essence for package storage (not more than 3 days) and no package may have a TI greater than ten.

C. 10 CFR PART 61

10 CFR Part 61 contains regulations for the siting and operation of near surface low-level waste disposal sites, as well as requirements for the classification and form of material which may be transferred (including transport) for disposal at such a facility. The requirements for waste classification and waste form are not technically equivalent to DOT requirements for radioactive material classification and packaging for purposes of transportation. However, shippers of radioactive waste inevitably must keep these Part 61 requirements in mind when preparing such low level waste (usually LSA or SCO materials) for shipment to a shallow land burial facility. Part 61 also contains specific requirements for radwaste manifest information and format which are more rigorous and detailed than the DOT requirements for shipping papers in 49 CFR Part 172.

NOTE: On March 27, 1995, NRC significantly revised its requirements for preparation of radwaste manifests (see 60 FR 15649).

Two important facts relating to 10 CFR 61:

1. The "Class A" and "Class B" waste designations pursuant to 10 CFR 61 are neither synonymous with nor the same as DOT's "Type A" and "Type B" package designations; and
2. The term "high integrity container" or "HIC" is a Part 61-related term and not a transport regulation-related term.

IX. OTHER REQUIREMENTS

A. TYPES OF CARRIERS AND CARRIER REQUIREMENTS

1. Common Carriers - Common and contract carriers are both "for hire" carriers serving the general public. Common carriers operate under procedures and charge rates that are established by carrier organizations. Contract carriers differ in that rates are usually agreed to between the shipper and carrier. A contract carrier serves only those shippers with whom he has a written contract. The authority of Federal and state agencies for issuing operating permits has been greatly reduced in recent years. Common and contract carriers do not own the property they transport for others and transportation of property for others is their principal business activity. Further, for radioactive material, common and contract carriers are exempt from the requirement to obtain a license from NRC or an Agreement State, to the extent that they transport licensed radioactive material for someone else. (10 CFR 30.13, 40.12 and 70.12).
2. Private Carriers - A private carrier generally owns the radioactive material which is being transported and transportation activities are incidental to their regular

business activity. A private carrier is always licensed by the NRC or an agreement state to possess and transport the radioactive material.

3. All carriers, common and contract, as well as private carriers, are subject to the same safety requirements of 49 CFR. An exception from the requirement for **certification** of the shipping papers is provided to a private carrier.

4. Carrier Requirements

The principal requirements which apply to all carriers are to:

- assure that the transport vehicle is properly placarded;
- assure that shipper has properly certified the shipment;
- maintain radiation control based on package transport index/separation table and the other transport requirements;
- report to DOT hazmat incidents involving fire, accident, breakage or suspected radioactive contamination (49 CFR 171.15, 171.16, 174.750, 175.700(b), 176.710, and 177.861);
- provide training to "Hazmat Employees"; and
- register with DOT and submit an annual fee when transporting certain radioactive material.

The sections specifically applicable to radioactive material in the modal Parts of the HMR begin at the following sections:

Rail	49 CFR 174.700;
Air	49 CFR 175.700 (but see §§175.33 and 175.75);
Water	49 CFR 176.700; and
Highway	49 CFR 177.842, 177.843, and 177.870(g).

B. REGISTRATION REQUIREMENTS

1. General - In 1992, DOT issued a new regulation⁵⁷ which established a national registration program for certain persons engaged in offering for transport and transporting of certain hazardous materials in foreign, interstate or intrastate commerce. The regulation was mandated by a provision in the Hazardous Materials Transportation Uniform Safety Act of 1990².
2. Applicability to radioactive material - The actual instances when the registration requirement (found in §§107.601-620) applies to radioactive material shippers or carriers are relatively infrequent, since registration is only required for persons who offer or transport:
 - Shipments of a "Highway Route Controlled Quantity";
 - Shipments of radioactive material in bulk packaging with a capacity equal to or greater than 3,500 gallons for liquids or gases, or more than 468 cubic feet for solids; or

- Shipment of 5000 pounds or more gross weight of any radioactive material for which vehicle placarding is required, which includes essentially:

- Exclusive use shipments of LSA or SCO materials when the gross weight of the materials is 5000 pounds or more; or
- 5000 pounds or more of packages bearing the RADIOACTIVE-YELLOW III labels, whether in an exclusive or non-exclusive-use vehicle.

3. Annual Assessment - The registration fee is \$300 annually, with \$50 of that fee devoted towards cost of administration of the system and the balance of \$250 devoted to funding public sector training and planning grants to states for emergency response planning and training (49 CFR Part 110).

C. MOTOR CARRIER SAFETY REQUIREMENTS

1. The Federal Motor Carrier Safety Regulations (FMCSR) are located in Parts 325-399 of 49 CFR. Regulatory Guidance in interpreting and compliance with the FMCSR, published in 1993, is available as a separately published training document⁴⁸.

2. Commercial Drivers License

"Commercial Driver's License" (CDL) means a license issued to an individual by a state or other jurisdiction, in accordance with the standards in 49 CFR 383, which authorizes that individual to operate a class of "commercial motor vehicle". For hazardous materials, a commercial vehicle may be of any size used in the transport of hazardous materials requiring vehicle placarding pursuant to 49 CFR 172. For radioactive material shipments the driver of a vehicle must have a CDL with a "hazardous materials endorsement" (49 CFR 383.93).

3. Hazardous Materials Driving/Parking Rules-§§49 CFR 397

Routing of radioactive material Shipments:

Placarded shipments - A carrier or any person operating a motor vehicle that contains a class 7 (radioactive) material as defined in 49 CFR 173.403 for which placarding is required under 49 CFR Part 172 shall ensure that the motor vehicle is operated on routes that minimize radiological risk [49 CFR 397.101(a)].

HRCQ Shipments -A carrier or person operating a motor vehicle containing a HRCQ of Class 7 (radioactive) material, as defined in 49 CFR 173.403, shall operate the motor vehicle only over "preferred routes". A preferred route is the Interstate Highway system or a state-designated alternate route selected by a state agency pursuant to 49 CFR 397.103. Pursuant to 49 CFR 397.101(d)(3), the driver of a HRCQ vehicle must be provided with a written route plan and must have received specific training within two years prior to the shipment and must have in his possession during the shipment a certificate of such training.

D. QUALITY ASSURANCE/QUALITY CONTROL REQUIREMENTS

1. DOT Requirements - DOT requirements for quality control are located in 49 CFR 173.474 and 173.475. These are titled "Quality Control for Construction of Packaging" and "Quality Control Requirements prior to each shipment of radioactive material", respectively. (10 CFR Part 71 of NRC requirements contains essentially identical paragraphs as §§71.85 and 71.87, entitled "Preliminary Determinations" and "Routine Determinations", respectively). The DOT quality control requirement to survey packages of radioactive material prior to shipment is the provision found in §173.475(i), which states, "Before each shipment of any radioactive material package the offeror must ensure, by examination or appropriate tests, that:

“External radiation and contamination levels are within the allowable limits specified in this subchapter.”

NOTE: This requirement to ensure compliance with radiation and contamination limits of §§173.441 and 173.443, has sometimes mistakenly been assumed to mean surveys or direct measurement must be made. Both sections give shippers latitude in their methods of ensuring compliance with the radiation and contamination limits, and DOT letters of interpretation have indicated that procedures other than measurements, such as, QA and QC, are acceptable means of ensuring compliance. However, if a compliance inspection during transportation determines that radiation or contamination levels exceed the limit, the shipper is subject to a citation.

2. NRC Requirements - In addition to the above-mentioned "generic" QC requirements of §§71.85 and 71.87, 10 CFR 71, Subpart H contains specific quality assurance requirements associated with the use of NRC-certified Type B and Fissile material transport packages used under the general licenses of §§71.12, 71.14 and 71.16. A major condition applying to the use of such NRC-certified packages is the requirement that each registered user of such a package must also have his quality assurance program associated with use of the package approved by NRC as having met applicable requirements of Subpart H, §§71.101-71.135.

E. SHIPMENT OF URANIUM HEXAFLUORIDE (UF₆)

Uranium hexafluoride is a unique material with respect to transportation requirements. It is a compound of hexavalent uranium and fluorine, which is used as the process gas in the gaseous diffusion plants to increase the concentration of the fissile isotope uranium-235 in the mixture of uranium isotopes found in naturally occurring uranium. During transportation, UF₆ exists as a crystalline solid and is shipped in metal cylinders at slightly reduced atmospheric pressure. (These same cylinders are actually constructed so as to have very high pressure capability for purposes of the high temperature operations and processes involved with production of the UF₆ in a gaseous state.) The material presents hazards due to its radioactivity, as well as to its corrosivity. Breach of a cylinder of solid UF₆ would result in a reaction product of the material with moisture in the air to produce a highly corrosive, but moderately radioactive gaseous cloud of material.

During transport, solid UF₆ is packaged and shipped essentially as either a non-fissile (LSA) or as a fissile material, depending on its enrichment in the U²³⁵ isotope. When the material is enriched in the U²³⁵ isotope beyond 1 %, it is shipped as and subject to the additional requirements for a fissile radioactive material.

Packaging requirements for UF₆, both fissile and LSA, are located in §173.420, which details the physical requirements for the pressure cylinders used to process and package UF₆. This section contains references to ANSI Standard N14.1⁵⁰ and United States Enrichment Corporation Report USEC-651⁴⁹. These documents are extremely important sources of information relative to the processing, packaging and transport of UF₆.

Quantity limits for shipment of enriched (fissile) UF₆ in the form of residual "heels" of material in "empty" cylinders are in §173.417(a)(7). Quantity limits for fissile UF₆ in metal cylinders overpacked in DOT Specification 20PF and 21PF protective overpacks are in §173.417(b)(5), or in the certificates for NRC certified UF₆ packages. The specifications for the DOT overpacks are in §§178.356 and 178.358.

Several NRC Certificates of Compliance for transport have been issued for packages which are used in shipment of fissile UF₆. These include Certificates number USA/4909/AF, USA/9196/AF, USA/9234/AF, and USA/6553/AF. Other useful sources of information, in addition to the ANSI N-14 Standard and document USEC-651, on packaging and shipment of UF₆, are NRC Information Notice 90-27³³ and NUREG-0383²².

F. DOT AND NRC ENFORCEMENT POLICIES

Violations of the regulations in 49 CFR and 10 CFR 71 may result in civil or criminal penalties, cease/desist orders, suspension orders, etc. Each Agency has published an enforcement policy which includes penalty guidelines, as follows:

1. DOT - DOT/RSPA hazardous materials transportation enforcement civil penalty guidelines are found in 49 CFR Part 107, Hazardous Material Program Procedures, Subpart D, Appendix A⁵⁹.
2. NRC - In July 1995, the NRC revised "General Statement of Policy and Procedures for NRC Enforcement Actions-Enforcement Policy", published by the NRC Office of Enforcement, NUREG 1600.

Import and export shipments must be made in accordance with the international regulations that are cited in 49 CFR 171.11 and 171.12. When import shipments are found to be in violation of the international air and sea transport regulations (which are essentially the same as the IAEA regulations) enforcement action against the foreign shipper or carrier can be taken by DOT by citing the applicable requirements in the ICAO or IMO regulations. If violations are found in radioactive material shipments being exported under the IMO or ICAO, the shipper or carrier may be charged with violating both the domestic and the international regulations.

X. IAEA REGULATIONS

IAEA's Regulations for the Safe Transport of Radioactive Material, Safety Series No. 6 are the model and standard for regulating the packaging and transportation of radioactive material both nationally and internationally. The regulations were initially developed in 1961, and are periodically revised.

In addition to SS-6, over the years the IAEA has produced several "companion" documents to supplement the SS-6 regulations, i.e., the "**what**" requirements. These include an advisory document SS-37^{14c}, i.e., the "**how**" document, and an explanatory document SS-7^{14b}, i.e., the "**why**" document, and SS-80^{14d} or the "**schedule**" document, which lists the specific requirements in schedule format by types of radioactive material consignments.

When the IAEA revised the regulations in 1996, the Regulations for the Safe Transport of Radioactive Material was designated as ST-1 within the new Safety Standards Series. It included revised schedules, which had previously been in SS-80. In 1998, the revised explanatory material that had been previously covered by SS-7, and the revised advisory material that had been SS-37, were incorporated into a new document that is designated ST-2 within the Safety Standards Series.

XI. USEFUL REFERENCES ON RADIOACTIVE MATERIAL TRANSPORTATION

STATUTES

1. Public Law 96-633, Title I, *Hazardous Materials Transportation Act*, 49 USC 1801-1812, January 3, 1975.
2. Public Law 101-615, *Hazardous Materials Transportation Uniform Safety Act of 1990*, 49 USC 1801-1819, December, 1990.
3. Public Law 103-311, *Hazardous Materials Transportation Authorization Act of 1994*, August 26, 1994.
4. Atomic Energy Act of 1954 (As Amended) 42 U.S.C., Chapter 23) and Section 301 Of the "Energy Reorganization Act of 1974, As Amended" (42 U.S.C. 5841).

REGULATIONS

5. U.S. Department of Transportation, Title 49, Code of Federal Regulations, Subchapter C-*Hazardous Materials Regulations*, Parts 171-178.
6. U.S. Nuclear Regulatory Commission, Title 10, Code of Federal Regulations, Chapter 1, Part 71, *Packaging and Transportation of Radioactive material*.
7. U.S. Department of Transportation, Office of Motor Carrier Safety, Federal Motor Carrier Safety Regulations, 49 CFR Parts 383 and 390-397.
8. U.S. Dept of Transportation and U.S. Nuclear Regulatory Commission, *Transportation of Radioactive Materials; Memorandum of Understanding*, 44 F.R. 38690, July 2, 1979.
9. U.S. Postal Service, Publication No. 6, March 1990, U.S. Postal Service, 475 L'Enfant Plaza, SW, Washington DC 20260, Attn: Business Mail Acceptance.

TEXTBOOKS

10. Moghissi, et al., "Regulation of Nuclear Waste Transportation", Chapter 10 in *Radioactive Waste Technology*, published by American Society of Mechanical Engineers, 1986.
11. Schleien, B., *The Health physics and Radiological Health Handbook*. Revised Edition, Chapter 14, "Nuclear Transportation Including Shipment of Low-Level Waste", published by Scinta, Inc., Silver Spring MD, 1992.
12. Willis, C.A., *Health Physics Annotated Bibliography*, Chapter 16, "Transportation", Published by the Baltimore-Washington Chapter of the Health Physics Society, Silver Spring, MD, 1989.

13. Gibson, R., The Safe Transport of Radioactive Materials, Pergamon Press, 1966.

INTERNATIONAL REFERENCES

14. International Atomic Energy Agency safety standards and guides on transport of radioactive material, published by IAEA, Vienna, Austria:
- a. Safety Series No. 6, *Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990)*, 1990, STI/PUB/866.
 - b. Safety Series No. 7, *Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition)*, Second Edition, (As Amended 1990), STI/PUB/867.
 - c. Safety Series No. 37, *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition)*, Third Edition (As Amended 1990). STI/PUB/868.
 - d. Safety Series No. 80, *Schedule of Requirements for the Transport of Specified Types of Radioactive Material Consignments (As Amended 1990)*, STI/PUB/869.
 - e. Training Course Series No. 1, *Safe Transport of Radioactive Material*, IAEA, Vienna, Austria, 1990, IAEA-TCS-1.
 - f. Safety Series No. 115, *International Basic Standards For Radiation Protection*, 1996.
 - g. IAEA -TECDOC-262, *Emergency Response Planning for Transport Accidents Involving Radioactive Material*, 1982.
 - h. Safety Series No. 87, *Emergency Response Planning and Preparedness for Transport Accidents Involving Radioactive Material*, 1988.
 - i. Safety Series No. ST-1, *Regulations for the Safe Transport of Radioactive Material*, 1996.

IAEA Publications are available for purchase from:

UNIPUB, Inc. - Bernan Associates
4611-F Assembly Drive
Lanham, MD. 20706
1-800-274-4888
(301) 459-7666

15. *United Nations Recommendations on the Transport of Dangerous Goods*, 9th Revised Edition (1995), and *UN Recommendations On the Transport of Dangerous Goods, Tests and Criteria*, 2nd Edition (1995), United Nations Sales Section, NY, NY 10017.

16. International Civil Aviation Organization, (ICAO), *Technical Instructions for the Safe Transport of Dangerous Goods By Air*, 1997-1998 Edition, DOC 9284-AN/905, ICAO, Montreal, Canada, 1996.
17. International Air Transport Association, (IATA), *Dangerous Goods Regulations*, 36th Edition, 1996, IATA, Montreal, Canada and Geneva Switzerland.
18. International Maritime Organization, IMO, London, 1996, Amendment No. 28.

PAMPHLETS

19. U.S. Department of Transportation (DOT), Research and Special Programs Administration, Washington, DC 20590, ATTN: (DHM-51).
 - a. *A Review of the Department of Transportation Regulations for Transportation of Radioactive Material*, Revised, 1983.
 - b. *Hazardous Materials Transportation Guides*, Revised February, 1991.
 - c. *A Guide For The Inspection of Radioactive Materials Shipments By Motor Vehicle or At Freight Facilities*, November, 1988.
 - d. *A Guide For the Inspection of Spent Nuclear Fuel Shipments By Motor Vehicle*, November, 1988.
 - e. *Hazardous Materials Training Modules: Compliance and Enforcement, How To Use the Hazardous Materials Regulations*, (No date, issued in 1993).
 - f. *1996 North American Emergency Response Guidebook- A Guidebook For First Responders During The Initial Phase of a Hazardous Materials Incident*.
20. U.S Department of Energy, Transportation Management Division, *Transporting Radioactive Material...Answers To Your Questions*, August, 1989.
21. U.S. Department of Energy, Transportation Management Division, *Emergency Preparedness For Transportation Incidents Involving Radioactive Material*, SAIC-89/135, May, 1989.

U.S. NUCLEAR REGULATORY COMMISSION PUBLICATIONS

22. NUREG-0383, *Directory of Certificates of Compliance for Radioactive Materials Packages*. Issued each year in October as three volumes:
 - a. *Volume 1-Report of NRC Approved Packages*
 - b. *Volume 2-Certificates of Compliance*
 - c. *Volume 3-Report of NRC Approved Quality Assurance Programs for Radioactive Materials Packages*

23. NRC Regulatory Guides, Division 7, *Transportation*:
- a. Reg Guide 7.1, *Administrative Guide For Packaging and Transporting Radioactive Material*, 6/74.
 - b. Reg Guide 7.2, *Packaging and Transportation of Radioactively Contaminated Biological Materials*, 6/72.
 - c. Reg Guide 7.3, *Procedures For Picking Up and Receiving Packages of Radioactive Material*, 5/75.
 - d. Reg Guide 7.4, *Leakage Tests on Packages for Shipment of Radioactive Material*, 5/77.
 - e. Reg Guide 7.6, *Design Criteria For Structural Analysis of Shipping Cask Containment Systems*, 3/78.
 - f. Reg Guide 7.7, *Administrative Guide for Verifying Compliance With Packaging Requirements for Shipments of Radioactive Materials*, (8/77 for comment).
 - g. Reg Guide 7.8 *Load Combinations for the Structural Analysis of Shipping Casks*, 3/89.
 - h. Reg Guide 7.9, *Standard Format and Content of Part 71 Applications for Approval of Packaging of Type B and Large Quantity , and Fissile Radioactive Material*, 1/80.
 - i. Reg Guide 7.10, *Establishing Quality Assurance Programs for Packaging Used In the Transport of Radioactive Material*, 6/86.
 - j. Reg Guide 7.11, *Fracture Toughness Criteria of Base Material For Ferritic Steel Shipping Cask Containment Vessels With A Maximum Wall Thickness of 4 Inches (0.m)* 6/91.
 - k. Reg Guide 7.12, *Fracture Roughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater Than 4 inches (0.1 m), But Not Exceeding 12 inches (0.3 m)*, 6/91.

NRC INFORMATION NOTICES AND BULLETINS, (IN's)

- 24. NRC Bulletin 95-01, "Quality Assurance Program For Transportation of Radioactive Material, 1/13/95.
- 25. IN 93-07, Classification of Transportation Emergencies, 2/1/93.
- 26. IN 93-05, Locking of Radiography Devices, 1/14/93.
- 27. IN 92-71, Employee Training and Shipper Registration Requirements For Transporting Radioactive Materials, 10/28/92.
- 28. IN 91-35, Labeling Requirements For Transporting Multi-Hazard Radioactive Materials, 6/7/91.
- 29. IN 90-82, Requirements For Use of Nuclear Regulatory Commission (NRC) Approved Transport Packages For Shipment of Type A Quantities of Radioactive Material, 12/31/90.
- 30. IN 90-66, "Incomplete Draining and Drying Of Shipping Casks", October 25, 1990.

31. IN 90-56, Inadvertent Shipment of a Radioactive Source In A Container Thought To Be Empty, 9/4/90.
32. IN 90-35, "Transportation of Type A Quantities of Nonfissile Radioactive Materials", 5/24/90.
33. IN 90-27, Clarification of Recent Revisions to the Regulatory Requirements For Packaging of Uranium Hexafluoride (UF₆) For Transportation, 4/30/90.
34. IN 89-74, Clarification of Transportation Requirements Applicable To Return of Spent Radio pharmacy Dosages From Users To Suppliers, 11/7/89.
35. IN 88-101, "Shipment of Contaminated Equipment Between Nuclear Power Stations", 12/28/88.
36. IN 88-33, Recent Problems Involving The Model Spec 2-T Radiographic Exposure Device, 5/27/88.
37. NRC Bulletin 88-06, Actions To Be Taken For The Transportation of Model Spec 2-T Radiographic Exposure Device, 6/14/88.
38. IN 87-47, Transportation of Radiographic Devices, 10/5/87.
39. IN 87-31, "Blocking, Bracing and Securing of Radioactive Material Packages In Transportation", 7/18/87.
40. IN 86-67, Portable Moisture/Density Gauges: Recent Incidents and Common Violations of Requirements For USE, Transportation and Storage, 8/15/86.
41. IN 85-46, "Clarification of Several Aspects of Removable Radioactive Surface Contamination Limits For Transport Packages", 6/18/85.
42. IN 84-14, Highlights of Recent Transport Regulatory Revisions By DOT and NRC, 3/2/84.
43. IN 80-32 (Rev 1), Clarification of Certain Requirements For Exclusive Use Shipments of Radioactive Materials, 2/12/82.
44. IN 80-32, Clarification of Certain Requirements For Exclusive-Use Shipments of Radioactive Material, 8/29/80.
45. NRC IE Bulletin 79-19, Packaging of Low-Level Waste For Transport, 8/10/79.
46. NRC Bulletin 94-02, Corrosion Problems in Certain Stainless Steel Packagings Used To Transport Uranium Hexafluoride, 11/14/94.

MISCELLANEOUS REFERENCES

47. Federal Emergency Management Agency, Guidance for Developing State, Tribal, and Local Radiological Emergency Response Planning and Preparedness for Transportation Accidents, FEMA-REP-5, Revision 1, June, 1992.
48. U.S. Department of Transportation , Federal Highway Administration, Regulatory Guidance for the Federal Motor Carrier Safety Regulations-Q&A, FHWA-MC-94-009, 1994. (Elaborates upon Guidance and interpretations published on 11/1793 at 58 F.R. 60734, No. 220.)
49. USEC-651, Revision 8, 1997, Uranium Hexafluoride - A Manual of Good Handling Practices, United States Enrichment Corporation, Bethesda, MD 20817.
50. N14.1-1995, Uranium Hexafluoride-Packaging For Transport, American National Standards Institute, 1430 Broadway, NY, NY.
51. DOE/WHC-EP-0558, Test and Evaluation Document for DOT Specification 7A Type A Packaging, Westinghouse Hanford Company, Richland, Washington, (DOE Contractor), 1990 (two revisions issued).
52. MLM-2228, Certification of ERDA Contractor' Packaging With Respect To Compliance With DOT Specification 7A Performance Requirements", (1975, 1976, 1977) Mound Laboratory, Monsanto Research Corporation, Miamisburg, Ohio, (DOE Contractor).
53. MLM-3245, DOE Evaluation Document For DOT-7A Type A Packaging, Mound Laboratory, Miamisburg, Ohio, March, 1987.
54. RSPA/OHMIT/92-06, "TRAINING-It's The Law", Brochure prepared by DOT/RSPA, Office of Hazardous Materials Initiatives and Training, October, 1992.
55. EPRI TR-102662, Guidance on NEW DOT Training Requirements for Hazardous Materials Employees, Electric Power Research Institute, Palo Alto, CA., July, 1993.
56. Docket HM-126F, U.S. Department of Transportation, RSPA, Training for Safe Transportation of Hazardous Materials, Final Rule, Federal Register, 57 F.R. 20994, (5/15/93); 57 F.R. 22181, (5/27/92), 59 F.R. 20994 (1/22/93).
57. Docket HM-208, U.S. Department of Transportation, RSPA, Hazardous Materials Transportation; Registration and Fee Assessment Program, Final Rule, Federal Register, 57 F.R. 30620, 7/9/92.
58. Docket HM-126C, U.S. Department of Transportation, RSPA, Emergency Response Information Requirements, Final Rule; 54 F.R. 27138 (6/27/89), 55 F.R. 870 (1/10/90).
59. Docket HM-207D, U.S. Department of Transportation, RSPA, Hazardous Materials Regulations; Penalty Guidelines", Final Rule, 60 F.R. 12139, March 6, 1995.

60. U.S. Nuclear Regulatory Commission, Office of Enforcement, 10 CFR Part 2, Policy and Procedure for Enforcement Actions; Removal, 60 F.R. 34380, June 30, 1995.
61. Environmental Protection Agency's (EPA), "Radiation Protection Guidance to Federal Agencies for Occupational Exposure: Recommendations Approved By the President", 52 F.R. 2822, January 27, 1987.
62. "Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects," NUREG-1608, US. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards - Washington, DC, U.S. Department of Transportation, Research and Special Programs Administration - Washington, DC.
63. Docket HM-169A, U.S. Department of Transportation, RSPA, Hazardous Materials; Transportation Regulations; Compatibility with Regulations of the International Atomic Energy Agency; Final Rule, 60 F.R. 50292, September 28, 1995.

**APPENDIX A
NOMENCLATURE AND SI UNITS**

Multiplication Factors		Prefix	Symbol	
1,000,000,000,000,000,000	=	10^{18}	exa	E
1,000,000,000,000,000	=	10^{15}	peta	P
1,000,000,000,000	=	10^{12}	tera	T
1,000,000,000	=	10^9	giga	G
1,000,000	=	10^6	mega	M
1,000	=	10^3	kilo	k
100	=	10^2	hecto	h
10	=	10^1	deka	da
0.1	=	10^{-1}	deci	d
0.01	=	10^{-2}	centi	c
0.001	=	10^{-3}	milli	m
0.000,001	=	10^{-6}	micro	u (or μ)
0.000,000,001	=	10^{-9}	nano	n
0.000,000,000,001	=	10^{-12}	pico	p
0.000,000,000,000,001	=	10^{-15}	femto	f
0.000,000,000,000,000,001	=	10^{-18}	atto	a

RADIOLOGICAL

The Curie and Becquerel are units of measure of the quantity or activity of radioactive material which indicates the rate that atoms in the material are giving off radiation or disintegrating. The Curie (Ci) is equal to 37 billion disintegrations per second while the Becquerel (Bq) is equal to only one disintegration per second. Thus, for example, one Curie is equal to 37 gigabecquerels or 0.037 terabecquerels; in symbols, $1 \text{ Ci} = 37 \text{ GBq} = 0.037 \text{ TBq}$.

The rem and Sievert (Sv) are units of radiation dose (technically, of dose equivalent) absorbed by the body. A Sievert is equal to 100 rem, or $1 \text{ Sv} = 100 \text{ rem}$. One one-thousandth of this would be one millisievert, or 100 millirem. In symbols, $1 \text{ mSv} = 100 \text{ mrem}$.

EQUIVALENTS FOR CONVERSIONS

Quantity (Activity)

$$1 \text{ TBq} = 27 \text{ Ci} = 27,000 \text{ mCi}$$

$$1 \text{ GBq} = 0.027 \text{ Ci} = 27 \text{ mCi} = 27,000 \text{ } \mu\text{Ci}$$

$$1 \text{ MBq} = 0.000027 \text{ Ci} = 0.027 \text{ mCi} = 27 \text{ } \mu\text{Ci}$$

$$1 \text{ Ci} = 0.037 \text{ TBq} = 37 \text{ GBq} = 37,000 \text{ MBq}$$

$$1 \text{ mCi} = 0.000037 \text{ TBq} = 0.037 \text{ GBq} = 37 \text{ MBq}$$

$$1 \text{ } \mu\text{Ci} = 0.037 \text{ MBq} = 37,000 \text{ Bq}$$

$$1 \text{ nCi} = 0.000037 \text{ MBq} = 37 \text{ Bq}$$

$$1 \text{ pCi} = 0.037 \text{ Bq} = 37 \text{ mBq}$$

Radiation level (Dose equivalent rate)

$$1 \text{ Sv/h} = 100 \text{ rem/h} = 100,000 \text{ mrem/h}$$

$$1 \text{ mSv/h} = 0.1 \text{ rem/h} = 100 \text{ mrem/h}$$

$$1 \text{ } \mu\text{Sv/h} = 0.0001 \text{ rem/h} = 0.1 \text{ mrem/h}$$

$$1 \text{ rem/h} = 0.01 \text{ Sv/h} = 10 \text{ mSv/h} = 10,000 \text{ } \mu\text{Sv/h}$$

$$1 \text{ mrem/h} = 0.00001 \text{ Sv/h} = 0.01 \text{ mSv/h} = 10 \text{ } \mu\text{Sv/h}$$

USE OF CONVERSION FACTORS

To convert a value from one system of units to the other:

First, in the left column find the unit you wish to convert from.

Second, find the factor in that line for the unit you wish to convert to.

Third, multiply your original value by that factor and the result will be the value in the new unit.

Example: To convert 20 mCi to its value in MBq:

Go to the line which starts with ? 1 mCi? .

The factor in that line for MBq is 37.

The value in MBq is $20 \times 37 = 740$, i.e., $20 \text{ mCi} = 740 \text{ MBq}$.