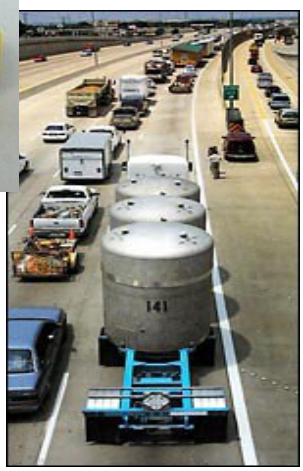
# RADIOACTIVE MATERIALS PACKAGING AND TRANSPORTATION BASIC PRIMER




DANA M. WILLAFORD
U.S. DEPARTMENT OF ENERGY
OAK RIDGE OFFICE
willaforddm@oro.doe.gov

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# Purpose and Use of this Manual

This manual was prepared by the U.S. Department of Energy (DOE) to assist in training DOE federal and contractor hazardous materials employees involved with radioactive material packaging and transportation. This manual is intended for training purposes only and should not be used to determine compliance with the hazardous materials regulations.

This manual should not be used by itself. It must be used with simultaneous reference to all current, applicable regulations found in the Code of Federal Regulations (CFR) and in DOE Orders. It includes discussion of the fundamentals for all hazardous materials, but has emphasis on radioactive material packaging and transportation requirements. At a minimum, the following references are required to gain the maximum benefit from this manual:

- 49 CFR 100-185, current edition
- 10 CFR 71, current edition
- 40 CFR 261–263, current edition
- 40 CFR 761, current edition
- 40 CFR 61, current edition
- International Air Transport Association (IATA) *Dangerous Goods Regulations*, current edition
- DOE Order 460.1B, *Packaging and Transportation Safety*, April 4, 2003
- DOE Guide 460.1-1, *Packaging and Transportation Safety*, June 5, 1997
- DOE Order 460.2A, *Departmental Materials Transportation and Packaging Management,* December 22, 2004
- DOE Order 461.1A, *Packaging and Transfer or Transportation of Materials of National Security Interest*, April 26, 2004
- DOE Manual 461.1-1, *Packaging and Transfer of Materials of National Security Interest Manual*, September 29, 2000
- Nuclear Regulatory Commission NUREG 1608, *Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Object*, 1998

The CFRs are available from the Government Printing Office or commercial vendors. Online versions are available at http://www.gpoaccess.gov/cfr/index.html. The IATA regulations are available from commercial vendors. Nuclear Regulatory Commission NUREG-1608 may be downloaded at http://rampac.energy.gov/. DOE directives are available online at http://www.directives.doe.gov/

This manual may be reproduced and used for training purposes only if the entire document is reproduced in full, without alteration, addition, or deletion. This manual will be routinely updated to reflect the current regulations. Comments, suggestions, or corrections should be directed to Dana M. Willaford, DOE Oak Ridge Office, at willaforddm@oro.doe.gov.

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# Table of Contents


Acronyms, Abbreviations, and Scientific Terms ..... iii
List of Figures ..... v
List of Tables ..... vi
Nomenclature and SI Units ..... vii
Equivalents for Conversions (Quantity/Activity) ..... viii
Source Documents and References ..... ix
CHAPTER 1 - INTRODUCTION AND OVERVIEW OF HAZARDOUS MATERIALS REGULATIONS ..... 1-1
1.1 INTRODUCTION ..... 1-2
1.2 DOMESTIC REGULATIONS ..... 1-2
1.3 INTERNATIONAL RECOMMENDATIONS AND REGULATIONS ..... 1-4
1.4 LAYOUT OF THE REGULATIONS ..... 1-5
1.5 FUNCTIONS COVERED BY THE HAZARDOUS MATERIALS REGULATIONS ..... 1-7
1.6 APPLICABILITY OF THE DOT REGULATIONS TO DOE CONTRACTORS ..... 1-8
CHAPTER 2 - HAZARDOUS MATERIAL FUNDAMENTALS ..... 2-1
2.1 HOW TO USE THE HAZARDOUS MATERIALS REGULATIONS ..... 2-1
2.2 DEFINITION OF TERMS ..... 2-3
2.3 DETERMINING APPLICABLE REQUIREMENTS ..... 2-4
2.4 THE IDENTIFICATION AND CLASSIFICATION PROCESS ..... 2-4
2.5 HAZARDOUS MATERIALS TABLE—ROADMAP INTO THE REGULATIONS ..... 2-9
2.6 LIST OF DANGEROUS GOODS IN THE AIR AND WATER REGULATIONS ..... 2-17
2.7 HAZARDOUS SUBSTANCES [SECTION 172.101, APPENDIX A, TABLES 1 AND 2] ..... 2-18
2.8 MARINE POLLUTANTS ..... 2-20
2.9 REVIEW QUESTION SET 1 ..... 2-21
2.10 HAZARDOUS WASTE ..... 2-24
2.11 REVIEW QUESTION SET 2 ..... 2-28
CHAPTER 3 - RADIOACTIVE MATERIAL TRANSPORT FUNDAMENTALS ..... 3-31
3.1 INTRODUCTION ..... 3-2
3.2 DOMESTIC REGULATIONS ..... 3-3
3.3 THE NRC'S TRANSPORT REGULATIONS ..... 3-4
3.4 WHEN DOES THE DOT HAVE JURISDICTION? ..... 3-5
3.5 INTERNATIONAL REGULATIONS ..... 3-7
3.6 IMPORTANT RADIOACTIVE MATERIAL DEFINITIONS ..... 3-7
3.7 PURPOSE OF THE RADIOACTIVE MATERIAL TRANSPORTATION REGULATIONS ..... 3-8
3.8 DETERMINING RADIOACTIVE MATERIAL SHIPMENT REQUIREMENTS ..... 3-8
3.9 THE $A_1/A_2$ SPECTRUM OF PACKAGE ACTIVITY LIMITS ..... 3-11
3.10 DETERMINING RQ VALUES FOR RADIOACTIVE MATERIAL ..... 3-23
3.11 TYPES OF RADIOACTIVE MATERIAL SHIPMENTS ..... 3-24
3.12 RADIOACTIVE MATERIAL SHIPMENTS BY AIR AND WATER ..... 3-25
3.13 REVIEW QUESTION SET 3 ..... 3-27
CHAPTER 4 - EXCEPTED PACKAGING SHIPMENTS ..... 4-1
4.1 EXCEPTED QUANTITY RADIOACTIVE MATERIAL SHIPMENTS ..... 4-2
4.2 REVIEW QUESTION SET 4 ..... 4-7
4.3 REVIEW QUESTION SET 5 ..... 4-8
CHAPTER 5 - LOW-SPECIFIC ACTIVITY (LSA) MATERIAL AND SURFACE-CONTAMINATED OBJECTS (SCOs) ..... 5-1
5.1 INTRODUCTION ..... 5-2
5.2 DEFINITIONS OF LSA AND SCO ..... 5-2
5.3 INSIGHTS FROM NRC NUREG-1608 ..... 5-4
5.4 ACTIVITY LIMITS, DOSE RATES, AND HAZARD COMMUNITCATON REQUIREMENTS FOR LSA AND SCO SHIPMENTS ..... 5-6
5.5 PACKAGING REQUIREMENTS FOR LSA MATERIAL AND SCO ..... 5-7
5.6 REVIEW QUESTION SET 6 ..... 5-10
CHAPTER 6 - FISSILE MATERIAL ..... 6-1
6.1 INTRODUCTION ..... 6-2

6.2 FISSILE MATERIAL EXCEPTIONS ..... 6-2
6.3 FISSILE MATERIAL PACKAGING AND SHIPPING REQUIREMENTS ..... 6-3
6.4 REVIEW QUESTION SET 7 ..... 6-8
CHAPTER 7 - PACKAGING ..... 7-1
7.1 INTRODUCTION ..... 7-2
7.2 PACKAGING PERFORMANCE STANDARDS ..... 7-2
7.3 PACKAGING RESPONSIBILITIES ..... 7-3
7.4 SELECTING THE CORRECT PACKAGING ..... 7-6
7.5 PACKAGING STANDARDS ..... 7-7
7.6 SMALL QUANTITY EXCEPTIONS ..... 7-8
7.7 MATERIALS OF TRADE EXCEPTIONS ..... 7-9
7.8 LAB PACKS ..... 7-9
7.9 SALVAGE DRUMS ..... 7-10
7.10 OVERPACKS ..... 7-10
7.11 EMPTY PACKAGING ..... 7-11
7.12 SPECIAL PERMITS (PREVIOUSLY KNOWN AS EXEMPTIONS) ..... 7-11
7.13 REVIEW QUESTION SET 8 ..... 7-13
7.14 RADIOACTIVE MATERIAL PACKAGING ..... 7-15
7.15 EXCEPTED PACKAGING ..... 7-16
7.16 INDUSTRIAL PACKAGING ..... 7-17
7.17 TYPE A PACKAGING ..... 7-18
7.18 TYPE B PACKAGING ..... 7-22
7.19 TYPICAL TYPE B PACKAGES ..... 7-26
7.20 QUALITY CONTROL AND QUALITY ASSURANCE REQUIREMENTS ..... 7-26
7.21 RESTRICTIONS ON PACKAGING USED FOR DOMESTIC AND INTERNATIONAL SHIPMENTS ..... 7-27
7.22 REVIEW QUESTION SET 9 ..... 7-29
CHAPTER 8 - CONTROLS FOR RADIOACTIVE MATERIAL SHIPMENTS ..... 8-1
8.1 INTRODUCTION ..... 8-2
8.2 TRANSPORT INDEX ..... 8-2
8.3 CRITICALITY CONTROL ..... 8-2
8.4 EXCLUSIVE USE AND CLOSED TRANSPORT VEHICLE PROVISIONS ..... 8-3
8.5 RADIATION LEVELS ..... 8-5
8.6 CONTAMINATION LIMITS ..... 8-9
8.7 REVIEW QUESTION SET 10 ..... 8-13
CHAPTER 9 - COMMUNICATION ..... 9-1
9.1 INTRODUCTION ..... 9-2
9.2 MARKING REQUIREMENTS ..... 9-2
9.3 RADIOACTIVE MATERIAL PACKAGE MARKING ..... 9-4
9.4 REVIEW QUESTION SET 11 ..... 9-6
9.5 GENERAL LABELING REQUIREMENTS ..... 9-7
9.6 ADDITIONAL LABELING REQUIREMENTS ..... 9-7
9.7 LABELING REQUIREMENTS FOR RADIOACTIVE MATERIAL ..... 9-8
9.8 REVIEW QUESTION SET 12 ..... 9-12
9.9 PLACARDING ..... 9-14
9.10 PLACARDING REQUIREMENTS FOR RADIOACTIVE MATERIAL ..... 9-16
9.11 REVIEW QUESTION SET 13 ..... 9-19
9.12 SHIPPING PAPERS ..... 9-21
9.13 EMERGENCY RESPONSE INFORMATION ..... 9-24
9.14 HAZARDOUS WASTE MANIFEST ..... 9-25
9.15 REVIEW QUESTION SET 14 ..... 9-26
9.16 REVIEW QUESTION SET 15 ..... 9-27
9.17 SHIPPING DOCUMENTATION FOR RADIOACTIVE MATERIAL ..... 9-33
9.18 EXAMPLES OF SHIPPING DOCUMENTATION ..... 9-38
9.19 REVIEW QUESTION SET 16 ..... 9-50
CHAPTER 10 - URANIUM HEXAFLUORIDE ..... 10-1
10.1 $UF_6$ PROPERTIES ..... 10-2
10.2 $UF_6$ CYLINDERS AND SHIPPING REQUIREMENTS ..... 10-2

## Acronyms, Abbreviations, and Scientific Terms

| | |
|---|---|
| α | alpha |
| β | beta |
| γ | gamma |
| ALARA | as low as reasonably achievable |
| Am | americium |
| ANSI | American National Standards Institute |
| ASME | American Society of Mechanical Engineers |
| Be | beryllium |
| Bq | becquerel (SI basic unit of activity) |
| C | carbon |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| Cf | californium |
| CFR | Code of Federal Regulations |
| Ci | curie (basic unit of activity) |
| Cm | curium |
| cm | centimeter |
| $cm^2$ | square centimeter |
| $cm^3$ | cubic centimeter |
| Co | cobalt |
| Cs | cesium |
| CSI | criticality safety index |
| DOE | Department of Energy |
| DOT | Department of Transportation |
| DOT 7A | Department of Transportation Specification 7A |
| dpm | disintegrations per minute |
| EPA | Environmental Protection Agency |
| FMCSR | Federal Motor Carrier Safety Regulations |
| g | gram |
| GBq | gigabecquerel |
| $^3H$ | tritium |
| HMR | Hazardous Material Regulations |
| HMT | Hazardous Materials Table |
| hr | hour |
| IAEA | International Atomic Energy Agency |
| IATA | International Air Transport Association |
| ICAO | International Civil Aviation Organization |
| IMDG | International Maritime Dangerous Goods |
| IMO | International Maritime Organization |
| $in^3$ | cubic inches |
| IP | industrial packaging |
| ISO | International Standards Organization |
| kBq | kilobecquerel |
| kg | kilogram |
| lb | pound |
| LSA | low-specific activity |
| $m^3$ | cubic meters |
| MBq | megabecquerel |
| mCi | millicurie |
| mg | milligram |
| mL | milliliter |
| mm | millimeter |
| mrem | millirem |

| | |
|---|---|
| mSv | millisievert |
| n.o.i. | not otherwise indexed |
| n.o.i.b.n. | not otherwise indexed by name |
| n.o.s. | not otherwise specified |
| Np | neptunium |
| NRC | Nuclear Regulatory Commission |
| ORM | other regulated material |
| PCB | polychlorinated biphenyl |
| Pd | palladium |
| PHMSA | Pipeline and Hazardous Materials Safety Administration |
| PIH | poison inhalation hazard |
| ppm | parts per million |
| Pu | plutonium |
| rem | roentgen equivalent man (unit of dose for ionizing radiation) |
| Ra | radium |
| RCRA | Resource Conservation and Recovery Act |
| Rn | radon |
| RQ | reportable quantity |
| SARA | Superfund Amendments and Reauthorization Act |
| SCO | surface-contaminated object |
| SI | International System of Units |
| Sr | strontium |
| ST-1 | *Regulations for the Safe Transport of Radioactive Material*, TS-R-1 |
| ST-2 | *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, Safety Guide, TS-G-1.1 |
| Sv | sievert (SI unit of dose) |
| TBq | terabecquerel |
| Tc | technetium |
| Th | thorium |
| TI | transport index |
| TSCA | Toxic Substances Control Act |
| U | uranium |
| µCi | microcurie |
| $UF_6$ | uranium hexafluoride |
| UN | United Nations |
| UN ID | United Nations identification |
| USEC | United States Enrichment Corporation |
| USPS | United States Postal Service |
| Y | yttrium |



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# List of Figures


Figure 1-1. Regulations and DOE directives affecting DOE transportation activities ..... 1-2
Figure 1-2. Layout of the CFR ..... 1-6
Figure 1-3. Participants in the hazardous materials transport system and their responsibilities ..... 1-8
Figure 2-1. Hazard classes and regulatory sections with defining criteria ..... 2-6
Figure 2-2. Decision chart to navigate the regulations ..... 2-7
Figure 2-3. Classification example ..... 2-8
Figure 2-4. When are PCBs regulated? ..... 2-11
Figure 2-5. Example of a basic description ..... 2-15
Figure 2-6. Process for hazardous waste determination ..... 2-24
Figure 2-7. Process for solid waste determination ..... 2-25
Figure 2-8. Process for recycled waste determination ..... 2-25
Figure 3-1. Applicability of DOT regulations to DOE contractors ..... 3-6
Figure 3-2. Regulatory scheme for transporting radioactive material ..... 3-8
Figure 3-3. Radioactive material shipping spectrum ..... 3-11
Figure 3-4. Exemption values for radionuclides (Section 173.436) ..... 3-12
Figure 3-5. Example of exemption calculations for radioactive material ..... 3-13
Figure 3-6. DOE contamination limits from 10 CFR 835 ..... 3-15
Figure 3-7. Extract of Section 173.435 ..... 3-16
Figure 3-8. Footnotes to the A1/A2 Table ..... 3-17
Figure 3-9. Thorium decay chain ..... 3-17
Figure 3-10. Secular equilibrium ..... 3-19
Figure 3-11. Decay product has a longer half-life—no equilibrium ..... 3-20
Figure 3-12. Unity equations ..... 3-20
Figure 3-13. Two examples of calculating and using the A2 values for mixtures ..... 3-22
Figure 3-14. Extract of Appendix A, Table 2, of the HMT ..... 3-23
Figure 4-1. Table 4 - Activity Limits for Limited Quantities, Instruments, and Articles ..... 4-3
Figure 4-2. Example of a limited quantity determination ..... 4-4
Figure 5-1. SCO-I and SCO-II maximum surface contamination levels ..... 5-3
Figure 6-1. Tables 71-1 and 71-2 on Mass Limits in Section 71.22 ..... 6-5
Figure 6-2. CSI equation for use with the DOT 7A Type A Packaging ..... 6-6
Figure 6-3. Example of CSI in a package Certificate of Compliance ..... 6-6
Figure 7-1. Examples of determining appropriate packaging ..... 7-7
Figure 7-2. Packaging pyramid ..... 7-15
Figure 7-3. Unyielding surface at Sandia National Laboratories used for drop tests ..... 7-24
Figure 8-1. Radiation level limitations (Section 173.441) ..... 8-6
Figure 8-2. Dose rates at surface and 1 meter for nonexclusive use shipments ..... 8-6
Figure 8-3. Allowable dose rates for an exclusive use shipment ..... 8-7
Figure 8-4. Allowable dose rates for an exclusive use shipment in a closed transport vehicle ..... 8-7
Figure 8-5. Maximum removable surface contamination levels in Table 9 (Section 173.443) ..... 8-9
Figure 8-6. DOE contamination limits from 10 CFR 835 ..... 8-11
Figure 9-1. Examples of RADIOACTIVE labels ..... 9-9
Figure 9-2. Label category based on TI and surface radiation level ..... 9-9
Figure 9-3. Placarding freight containers ..... 9-16
Figure 9-4. Basic description on a shipping paper derived from information in the HMT ..... 9-22

# List of Tables

Table 2-1. Suggested Tabs for 49 CFR ..... 2-2
Table 2-2. Important Definitions to Know in Section 171.8 ..... 2-4
Table 3-1. Uranium-238 and Uranium-235 Decay Series ..... 3-18
Table 8-1. Summary of Radiation Levels for Packages and Transport Vehicles ..... 8-8
Table 8-2. Summary of Package and Vehicle Contamination Limits (49 CFR 173.443) ..... 8-12
Table 9-1. Summary of Marking Requirements for Class 7 (Radioactive) Material Packages ..... 9-5
Table 9-2. Summary of Labeling Requirements for Radioactive Material Packages ..... 9-11
Table 9-3. Placarding Requirements for Radioactive Material Shipments ..... 9-18
Table 9-4. Summary of Shipping Paper Requirements for Radioactive Material Shipments ..... 9-36

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

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

## Equivalents for Conversions (Quantity/Activity)

| | |
|---|---|
| 1 TBq | = 27 Ci = 27,000 mCi |
| 1 GBq | = 0.027 Ci = 27 mCi = 27,000 µCi |
| 1 MBq | = 0.000027 Ci = 0.027 mCi = 27 µCi |
| 1 Ci | = 0.037 TBq = 37 GBq = 37,000 MBq |
| 1 mCi | = 0.000037 TBq = 0.37 GBq = 37 MBq |
| 1 µCi | = 0.037 MBq = 37,000 Bq |
| 1 nCi | = 0.000037 MBq = 37 Bq |
| 1 pCi | = 0.037 Bq = 37 mBq |

| | Radiation Level (Dose Equivalent Rate) |
|---|---|
| 1 Sv/hr | = 100 rem/hr = 100,000 mrem/hr |
| 1 mSv/hr | = 0.1 rem/hr = 100 mrem/hr |
| 1 µSv/hr | = 0.0001 rem/hr = 0.1 mrem/hr |
| 1 rem/hr | = 0.01 Sv/hr = 10 mSv/hr = 10,000 µSv/hr |
| 1 mrem/hr | = 0.00001 Sv/hr = 0.01 mSv/hr = 10 µSv/hr |

### Use of Conversion Factors

To convert a value from one system of units to another:

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. The result will be in the new unit.



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# Source Documents and References

In addition to the Department of Transportation (DOT), Nuclear Regulatory Commission (NRC), and Environmental Protection Agency regulations, the following references and resources were used in development of this training manual.


- International Atomic Energy Agency (IAEA) TS-R-1 (ST-1), *Regulations for the Safe Transport of Radioactive Material*, 1996 (revised)

- IAEA TS-G-1.1 (ST-2), *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, 2002

- DOT *Radioactive Material Regulations Review*, 2008 DRAFT

- NRC NUREG-1608, *Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects*, 1998

- NRC NUREG/CR-5342, *Assessment and Recommendations for Fissile-Material Packaging Exemptions and General Licenses Within 10 CFR Part 71*, 1998

- ORNL/M-5003, *The Radioactive Materials Packaging Handbook, Design, Operations, and Maintenance*, 1998

- *Red Book on Transportation of Hazardous Materials*, Second Edition, Lawrence W. Bierlein, 1988

- DOE UCID-21218, *Packaging Review Guide for Reviewing Safety Analysis Reports for Packaging,* Revision 3, 2008


Websites:

- Training materials and resources:
  - http://hazmat.dot.gov/training/training.htm
  - http://hazmat.dot.gov/pubs/pubs.htm
  - http://www.em.doe.gov/otem
- Technical resources:
  - http://www.nrc.gov/materials/transportation.html
  - http://rampac.energy.gov/
  - http://www-ns.iaea.org/tech-areas/radiation-safety/transport.htm
  - http://www.epa.gov/epaoswer/osw/

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# CHAPTER 1

# INTRODUCTION AND OVERVIEW OF HAZARDOUS MATERIALS REGULATIONS

## OBJECTIVES

- IDENTIFY REGULATORY AGENCIES THAT REGULATE HAZARDOUS MATERIALS PACKAGING AND TRANSPORTATION.
- UNDERSTAND THE LAYOUT OF THE VARIOUS HAZARDOUS MATERIALS REGULATIONS.
- RECOGNIZE WHICH FUNCTIONS ASSOCIATED WITH HAZARDOUS MATERIALS PACKAGING AND TRANSPORTATION ARE REGULATED.
- UNDERSTAND THE APPLICABILITY OF THE HAZARDOUS MATERIALS REGULATIONS.

## 1.1 INTRODUCTION

Hazardous material transportation is regulated by numerous international and domestic entities. The challenge for today's shippers, carriers, and packaging manufacturers is to identify which regulations apply so that all the requirements can be addressed. A summary of the principal safety and security regulations and U.S. Department of Energy (DOE) directives affecting DOE transportation activities are illustrated in the Figure 1-1 below.

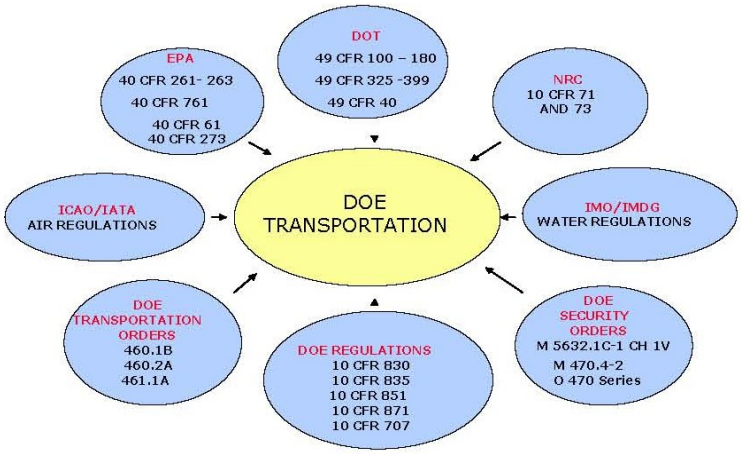


**Figure 1-1. Regulations and DOE directives affecting DOE transportation activities**

## 1.2 DOMESTIC REGULATIONS

### U.S. Department of Transportation

The federal hazardous materials transportation law (49 United States Code, *Transportation*, Section 5101 et. seq., formally called the Hazardous Materials Transportation Act, 49 United States Code, Section 1801) gives the Department of Transportation (DOT) jurisdiction for establishing safety regulations for the transport of hazardous material in foreign commerce and in interstate and intrastate commerce within the United States. A *hazardous material* as defined by the DOT is a substance or material, including a hazardous substance, in a quantity or form that may pose an unreasonable risk to health, safety, or property when transported in commerce. An explanation of transporting shipments in commerce is provided later in this chapter.

The DOT has promulgated regulations that specify the defining criteria for nine hazard classes of hazardous materials. Associated with each hazard class are specific packaging and hazard communication requirements. These requirements (along with the modal-specific operational provisions for air, rail, water, and highway shipments) are found in Title 49 Code of Federal Regulations (CFR), Parts 100–180. In addition to carriers and offerors (shippers) of hazardous material, the DOT Hazardous Materials Regulations (HMR) apply to persons who manufacture, mark, maintain, recondition, repair, or test packaging and packaging components used for transporting hazardous material.

### U.S. Environmental Protection Agency

The Environmental Protection Agency (EPA) promulgated regulations under several legislative acts: the Clean Water Act, the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); the Superfund Amendments and Reauthorization Act of 1986 (SARA); the Toxic Substances Control Act (TSCA); and the Clean Air Act. The Clean Water Act, CERCLA, and SARA identify materials considered to be hazardous substances that pose an environmental threat if released into the environment, and they establish the reportable quantity (RQ) levels that require notification in the event of a release. The DOT incorporates these values into its regulations and establishes communication requirements for packages and shipping papers.

The regulations promulgated under RCRA define material that is considered to be *hazardous waste* and which requires specific shipping documentation and package markings when the material is transported for disposal. The EPA defaulted to the DOT for material classification, packaging, and other communication requirements.

The TSCA regulations establish the requirements for the storage and disposal of polychlorinated biphenyls (PCBs) and prescribe the use of DOT-authorized packaging. The DOT regulates PCBs, in certain quantities, as environmentally hazardous substances and Class 9 material.

Under the Clean Air Act, the EPA established the National Emissions Standards for Asbestos Program. These regulations require hazard communication and specific documentation for asbestos shipments, but otherwise, they default to the DOT for packaging and shipping requirements.

### U.S. Nuclear Regulatory Commission

The Nuclear Regulatory Commission (NRC) is responsible for establishing packaging standards for fissile material, Type B quantities of radioactive material, low-specific activity (LSA) material, and surface-contaminated objects (SCOs) with dose rates exceeding 1 roentgen equivalent man (rem)/hour (hr) at 1 meter from the unshielded material. These are considered to be high-risk radioactive materials, and they require packages capable of withstanding severe accident conditions. All other radioactive material shipments are considered low risk, and the DOT is responsible for establishing the packaging standards for these materials.

### U.S. Postal Service

The transport of domestic mail by the United States Postal Service (USPS) is not subject to the HMR, as the shipments are not in commerce. However, for legal and safety reasons, the USPS requirements for transporting hazardous materials closely adhere to the HMR and also include many additional limitations and prohibitions.

The USPS specifies its requirements in the *Domestic Mail Manual*, Issue 55, and Publication 52, *Acceptance of Hazardous, Restricted, or Perishable Matter*. The DOT hazard classes and communication and packaging requirements form the foundation of the USPS regulations. In general, the USPS regulations prohibit hazardous materials, except ones that can qualify as other regulated material (ORM-D) and can be renamed with the proper shipping name ("consumer commodity") under 49 CFR. Under very restricted conditions, Class 7 material may be offered by the USPS. Any hazardous material requiring DOT labeling is prohibited, with the exception of some Division 6.2 material and dry ice requiring a Class 9 label.

DOE Regulations and Directives

DOE has regulations regarding the transport of plutonium (Pu) by air, radiation protection, quality assurance, and transportation activities that are not regulated by the DOT. The DOE Directives System has a number of DOE directives that address offsite shipments and onsite transfers of hazardous material. These directives are applicable to contractor activities when they are included in the contract with DOE.

All DOE activities must be conducted in accordance with DOE Policy 450.4, *Safety Management System Policy.* The DOE safety management system establishes a hierarchy of components to facilitate the orderly development and implementation of safety management throughout the DOE complex. The safety management system consists of six components: the objective, the guiding principles, the core functions, the mechanisms, the responsibilities, and implementation.

The DOE core functions of Integrated Safety Management provide the necessary structure for any work activity. The five core functions are (1) define the scope of work, (2) analyze the hazards, (3) develop and implement hazard controls, (4) perform the work within controls, and (5) provide feedback and continuous improvement.

*Key DOE Directives Affecting Transportation Activities by DOE and Contractors*

- DOE Order 460.1B, *Packaging and Transportation Safety*
- DOE Guide 460.1-1, *Implementation Guide for Use with DOE Order 460.1A*
- DOE Order 460.2A, *Departmental Materials Transportation and Packaging Management*
- DOE Manual 460.2-1A, *Radioactive Material Transportation Practices Manual*
- DOE Order 461.1A, *Packaging and Transfer or Transportation of Materials of National Security Interest*
- DOE Manual 461.1-1, *Packaging and Transfer of Materials of National Security Interest Manual*

*Ancillary Related Directives and Regulations*

- DOE Order 440.2B, *Aviation Management and Safety*
- DOE Manual 470.4-2, *Physical Protection*
- 10 CFR 830, *Nuclear Safety Management*
- 10 CFR 835,*Occupational Radiation Protection*
- 10 CFR 851, *Worker Safety and Health Program*
- 10 CFR 871, *Air Transportation of Plutonium*
- 10 CFR 707, *Workplace Substance Abuse Programs at DOE Sites*

## 1.3 INTERNATIONAL RECOMMENDATIONS AND REGULATIONS

### United Nations "Orange Book"

The United States participates as a member of the United Nations (UN) Committee of Experts on the Transportation of Dangerous Goods. The result of the deliberations of this committee (and a parallel committee on the transportation of explosives) is the UN "Orange Book" of recommendations on the transport of dangerous goods, including performance standards for packaging.

### International Maritime Organization

The International Maritime Organization (IMO) implements the UN recommendations in the International Maritime Dangerous Goods (IMDG) Code. The IMDG Code is generally followed or required by most international water carriers and is a viable option for domestic water shipments in the United States, subject to the provisions in 49 CFR 171.22, 171.23, and 171.25. The IMDG Code also identifies materials deemed to be marine pollutants under the International Convention for the Prevention of Pollution from Ships. These materials are also incorporated into the DOT regulations and have specific communication requirements associated with them.

### International Civil Aviation Organization

Under various international treaties involving air transportation, the International Civil Aviation Organization (ICAO) has adopted an Annex and Technical Instructions on the preparation of dangerous goods for air transport. The ICAO Technical Instructions are based on the UN recommendations and may be used in the United States in accordance with 49 CFR 171.22, 171.23, and 171.24.

Air carriers have adopted their own regulations through the International Air Transportation Association (IATA). The IATA *Dangerous Goods Regulations* are based on the ICAO Technical Instructions, but they are generally more restrictive in certain operational respects. Most domestic carriers have chosen to only accept shipments prepared under the ICAO regulations as implemented by the IATA regulations.

### International Atomic Energy Agency

Beginning in the 1950s, there was an effort to develop an international consensus on how radioactive material should be transported. The initial effort relied heavily on the standards used in the United States, which at that time were found in the Bureau of Explosives regulations. The first publication of the international standards was the 1961 edition of Safety Series No. 6, *Regulations for the Safe Transport of Radioactive Material,* issued by the International Atomic Energy Agency (IAEA). The 1967 edition of Safety Series No. 6 was adopted into the domestic regulations in 1968. Since that time, the United States has continued to incorporate these standards (with certain exceptions) into its domestic regulations. The current edition of 49 CFR is based on the 1996 edition of the international standards, *Regulations for the Safe Transport of Radioactive Material* (ST-1, revised). These regulations were incorporated into the domestic regulations by final rule on January 26, 2004, and were effective on October 1, 2004.

## 1.4 LAYOUT OF THE REGULATIONS

### Domestic Transportation Regulations: 49 CFR 100–180

The DOT HMR is found in 49 CFR 100–180. The primary goal of the HMR is the safety of the public and transportation workers. To minimize risks, the DOT established specific requirements for shipments of hazardous materials. These requirements fall into three general areas: (1) hazardous material identification and hazard communication, (2) packaging requirements, and (3) operational rules.

It is important to remember where you are within the outline of the regulations. See Figure 1-2 for the layout of the CFR book. For example, if the regulations provide an exception from any other requirements in the subchapter, e.g., see the wording in Section 173.4(a), then the rest of the requirements in Subchapter C (the HMR) do not apply.

**Layout of the CFR**

The Code of Federal Regulations follows the same basic outline used for most written material. Headings follow the descending order shown below.

| | |
|---|---|
| Title | Title 49 – Transportation |
| Subtitle | Subtitle B – Other Regulations Relating to Transportation |
| Chapter | Chapter I – Research and Special Programs Administration, Department of Transportation |
| Subchapter | Subchapter C – Hazardous Materials Regulations |
| Part | Part 173 – Shippers – General Requirements for Shipments and Packages |
| Subpart | Subpart I – Class 7 (Radioactive) Materials |
| Section | 173.427 |
| Paragraph | 173.427(a) |
| Subparagraph | 173.427(a)(6) |
| Sub-subparagraph | 173.427(a)(6)(i) |

**Figure 1-2. Layout of the CFR**

### EPA and NRC Regulations (40 CFR 260–263; 40 CFR 761; 40 CFR 61; 10 CFR 71)

The layouts of the EPA and NRC regulations are similar to the DOT regulations, as they are also published in the CFR. Determinations for actual shipments should be made by referring to the current set of regulations. The regulations can be found on the internet at http://www.gpoaccess.gov/cfr/index.html.

### USPS Regulations (*Domestic Mail Manual*, Issue 55, and Publication 52)

The USPS regulations for hazardous materials are provided in Publication 52, *Acceptance of Hazardous, Restricted, or Perishable Matter*, and in the *Domestic Mail Manual*. Publication 52 is written in a straightforward manner and has both a table of contents and an index for quick reference. The extracts from the *Domestic Mail Manual* provide cross-references to more updated DOT references than can be found in Publication 52, and it should be used in conjunction with that document. The *Domestic Mail Manual* and other useful reference material can be found on the internet at http://www.usps.com/businessmail101/mailcharacteristics/whatIsMailable.htm.

### IMDG Code

The IMDG Code is presently in a two-volume format that is issued biennially. Use of the IMDG Code is authorized for vessel shipments in 49 CFR 171.22, 171.23, and 171.25. Because the IMDG regulations are international, domestic terms like *hazardous waste*, *hazardous substances*, and *poison inhalation hazard* (PIH) do not appear in the IMDG Code. The requirements for these materials are addressed in 49 CFR 171.23(b). There is a grammatical difference between the IMDG regulations and the domestic regulations regarding use of the word *should*. In the IMDG Code, *should* indicates a mandatory rather than permissive requirement.

*Layout of the IMDG Code*

The IMDG Code consists of two volumes. Volume 1 contains the hazard class definitions and packing instructions. It includes definitions and packing, stowage, and segregation requirements. The equivalent of the DOT "Hazardous Materials Table" (HMT) is the "Dangerous Goods List," which

is contained in Volume 2. Volume 2 also contains the exceptions for limited quantities and the transport schedules for radioactive material.

ICAO *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (and the IATA *Dangerous Goods Regulations*)

The ICAO *Technical Instructions for the Safe Transport of Dangerous Goods by Air* are published biennially, and the current edition incorporates the requirements for radioactive material from the most recently published IAEA safety regulations. To the extent possible, the current Technical Instructions reflect the current edition of the UN Orange Book, *Recommendations on the Transport of Dangerous Goods*.

*Layout of the Technical Instructions*
The ICAO *Technical Instructions for the Safe Transport of Dangerous Goods by Air* are divided into nine Parts, with each Part divided into Chapters, and each Chapter divided into paragraphs and subparagraphs. A reference might therefore read "2;7.7.3.2," indicating Part 2, Chapter 7, paragraph 7.3, subparagraph 7.3.2. A table of contents and an index are provided to facilitate finding the sections easily.

Use of the Technical Instructions is authorized for domestic air shipments under 49 CFR 171.22, 171.23, and 171.24. Because the ICAO regulations are international, domestic terms like *hazardous waste*, and *hazardous substances* do not appear in the regulations. The requirements for these materials are addressed in 49 CFR 171.23(b). Domestic restrictions are shown as state variations in the Technical Instructions and in the carriers' regulations.

Carrier restrictions (e.g., specific requirements imposed by FedEx Corporation or Delta Airlines) are published annually in each carrier's requirements publication and the IATA *Dangerous Goods Regulations*. The IATA regulations do not have regulatory standing under the DOT, but they are a reprint of the ICAO Technical Instructions with additional carrier-specific requirements. For ease of instruction, this manual also references sections in the IATA *Dangerous Goods Regulations*.

Part 2 of the Technical Instructions details the various hazard classes and the "List of Dangerous Goods." Each of the first nine Chapters within this Part matches numerically with the hazard classes (i.e., Chapter 1 has requirements for Class 1 material, Chapter 2 has requirements for Class 2 material, etc.). The IATA *Dangerous Goods Regulations* have a similar format. In the IATA regulations, Part 3, Chapter 10, contains the requirements for multiple hazard classification similar to 49 CFR 173.2a, and Part 4 has the "List of Dangerous Goods" that is comparable to the HMT in 49 CFR.

IAEA Regulations

The IAEA *Regulations for the Safe Transport of Radioactive Material*, Safety Series, TS-R-1 (ST-1, revised), are the model and standard for regulating the packaging and transportation of radioactive material nationally and internationally. The regulations were initially developed in 1961, and they have been periodically revised ever since. In addition to the regulations, over the years the IAEA has produced several "companion" documents to supplement the regulations (i.e., the "what" and "how" requirements). These are now incorporated into the *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, Safety Guide, TS-G-1.1 (ST-2).

## 1.5 FUNCTIONS COVERED BY THE HAZARDOUS MATERIALS REGULATIONS

Title 49 CFR Part 171.1 states that the HMR applies to persons who:

- Transport hazardous materials in commerce.
- Cause hazardous materials to be transported in commerce.
- Manufacture or maintain hazardous materials packaging transported in commerce.

Therefore, the regulations establish the requirements for anyone who offers for transport or transports hazardous materials or who designs, manufactures, or uses packaging for transporting hazardous materials. The major parties involved in hazardous materials transportation are shown graphically below in Figure 1-3.

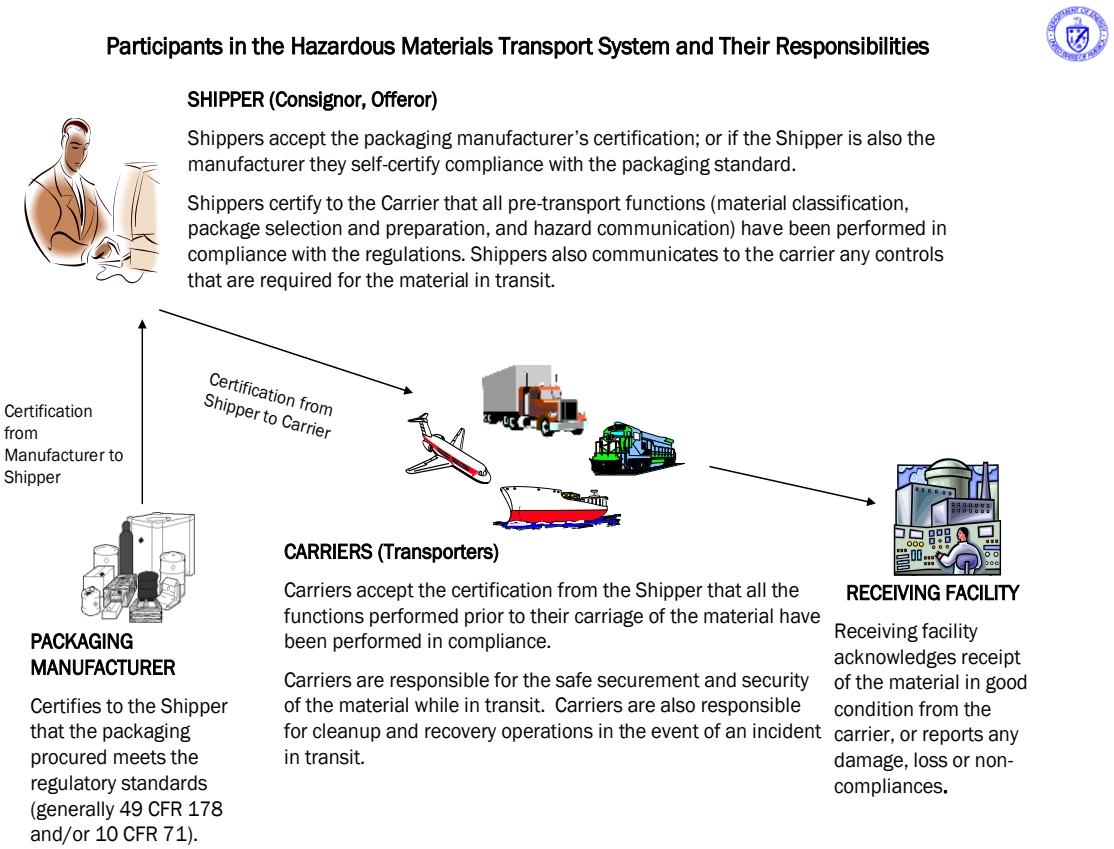


**Figure 1-3. Participants in the hazardous materials transport system and their responsibilities**

## 1.6 APPLICABILITY OF THE DOT REGULATIONS TO DOE CONTRACTORS

The question of jurisdiction is an important one for DOE contractors to understand. Determination of DOT jurisdiction requires examining the distinct operating environments. The determination is also a two-test process.

The first test involves the commercial nature of the transportation. The DOT HMR and various modal safety regulations apply whenever transportation occurs in commerce. *In commerce* has been interpreted and enforced by the DOT to be when the transportation is not conducted wholly by a governmental entity. Therefore, transportation of DOE material in a vehicle operated by a DOE employee (or by a DOE contractor that is a state university employee) is not in commerce and is not subject to the HMR or the various modal safety requirements.

***NOTE: Although offsite transportation activities performed by DOE contractors that are employees of a state university are not considered to be in commerce, DOE Order 460.1B requires that the contractor comply with the DOT regulations to the same extent as if the activity was in commerce.***

If the transportation is determined to be in commerce, the second test must be examined. The second test applies to the operating environment as it pertains to the public. Transportation of a hazardous material in commerce where the public has unrestricted access is subject to the HMR. Likewise, hazardous material in a nongovernmental, contractor-driven vehicle on a road with public access restricted by gates/guards (i.e., on a site) is not subject to the HMR.

The DOT Federal Motor Carrier Safety Regulations (FMCSR) apply whenever a vehicle is operated on, along, or across a *public road*. Whether the road is public is determined by who owns or leases it, maintains it, and enforces the traffic laws. Thus, a contractor commercial motor vehicle containing hazardous material operated on an unrestricted-access state, local, or city public highway is subject to the HMR and the FMCSA requirements.

Shippers should understand the definitions for pre-transportation functions that are covered by the HMR. (See the definitions in Sections 171.8 and 171.1 for applicability.) Anyone performing pre-transportation functions is subject to the applicable regulations.

The applicability of the DOT HMR to DOE contractors is summarized below:

- DOE contractors are either directly subject to the DOT regulations or required to comply with the DOT regulations by DOE directives whenever they prepare hazardous material shipments and/or offer them for transport and/or transport them on roads with unrestricted public access (offsite roads).
- DOE contractors preparing and/or transporting hazardous material on roads with restricted public access (onsite roads) are not directly regulated by the DOT, but they are subject to DOE directives that require contractors to conduct the shipments either in compliance with the DOT regulations or in a manner that provides an equivalent level of safety.
- Shipments prepared and/or conducted by DOE federal personnel (e.g., transportation safety or Federal Radiological Assistance Program team personnel) are not regulated by the DOT, regardless of what road is used for transportation. They are subject to the requirements in DOE directives and regulations.

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# CHAPTER 2
# HAZARDOUS MATERIAL FUNDAMENTALS

OBJECTIVES

- UNDERSTAND HOW TO USE THE HMT.
- UNDERSTAND IMPORTANT DEFINITIONS.
- BE ABLE TO DETERMINE IF A MATERIAL IS A HAZARDOUS MATERIAL, HAZARDOUS SUBSTANCE, HAZARDOUS WASTE, AND/OR A MARINE POLLUTANT.
- UNDERSTAND THE CONCEPTS OF IDENTIFICATION, CLASSIFICATION, CONTAINMENT, COMMUNICATION, AND CONTROL AS THEY RELATE TO HAZARDOUS MATERIAL PACKAGING AND TRANSPORTATION.
- UNDERSTAND HOW TO DETERMINE THE APPLICABILITY OF THE VARIOUS REGULATIONS FOR HAZARDOUS MATERIALS, WASTE, AND SUBSTANCES.

## 2.1 HOW TO USE THE HAZARDOUS MATERIALS REGULATIONS

It is necessary to understand the organization of the regulations and how the regulations are numbered. The beginning of Chapter 1 in 49 CFR contains an outline of the regulations. Note that the regulations are divided into subchapters, and the subchapters are divided into parts.

The HMR is basically contained in Subchapter C and consists of Parts 171–180. The specific regulations are numbered according to their location by part and section designation. For example, the placarding requirements are contained in Part 172, Section 500. The part and section designations are separated by a period (.), e.g., Section 172.500. More specific regulations may be identified by reference to a paragraph within a section, such as Section 172.500(a).

Note that there is a table of contents at the beginning of each part (Part 172, 173, etc.). This can be used to help find sections more easily and to identify individual subparts. Take a few minutes to familiarize yourself with the regulations by locating various parts and sections referenced in the table of contents.

Most of the regulations are contained in Subchapter C. Any time a specific regulation in Parts 171-180 states that certain materials are “not subject to this subchapter,” those materials are not considered to be covered by the HMR. Review Section 173.307 as an example. Note that carbonated beverages and several other items are "not subject to . . . this subchapter"; therefore, they are not subject to any of the HMR. Sometimes a regulation may state that certain items are not subject to a subpart. For example, review Section 172.500 and read paragraph (b). The materials listed in Section 172.500(b) are not subject to Subpart F, which covers placarding. However, these materials are subject to other parts of the regulations, such as the marking requirements in Subpart D.

To make it easier to find important regulations, it is suggested that you tab your regulations at each subject listed in Table 2-1. Review Section 171.9, “Rules of Construction,” since this section is important for understanding application of the regulations. Note the meaning of *shall*, *must*, *should*, *may*, and *may not*.

**Table 2-1. Suggested Tabs for 49 CFR**

| Subject | HMR Reference | Suggested Tab |
|---|---|---|
| Exemptions | Part 107 | 107 |
| Oil Spill Prevention Plans | Part 130 | OIL |
| Marine Pollutant | 171.4 | MP |
| Definitions/Abbreviations | 171.8 | DEF |
| Hazardous Materials Table | 172.101 | HMT |
| Appendix to HMT - Hazardous Substances | Appendix A | HAZ SUB (RQ) |
| Appendix to HMT - Marine Pollutants | Appendix B | MP TABLE |
| Special Provisions | 172.102 | SPEC PROV |
| Shipping Papers | 172.200 | SHIP PAP |
| Marking | 172.300 | MARKING |
| Labeling | 172.400 | LABEL |
| Placarding | 172.500 | PLACARD |
| Emergency Response Information | 172.600 | ER |
| Training | 172.700 | TRNG |
| Security | 172.800 | SECURITY |

**Table 2-1. Suggested Tabs for 49 CFR (continued)**

| Subject | HMR Reference | Suggested Tab |
|---|---|---|
| Precedence Table | 173.2a | CLASS |
| Materials of Trade | 173.6 | MOTS |
| Waste Packaging Exception | 173.12 | LAB PACK |
| Packaging - General Requirements | 173.24 | GEN PKG |
| Packaging - Additional Requirements, Non-Bulk | 173.24a | NON-BULK |
| Packaging - Additional Requirements, Bulk | 173.24b | BULK |
| Class 1 Explosives | 173.50 | CLASS 1 |
| Class 2 Gases | 173.115/173.116 | CLASS 2 |
| Class 3 Flammable/Combustible Liquid | 173.120/173.121 | CLASS 3 |
| Class 4 Flammable, Solid Spontaneously Combustible, Dangerous When Wet | 173.124/173.125 | CLASS 4 |
| Class 5 Oxidizer, Organic Peroxide | 173.127/173.128 | CLASS 5 |
| Class 6 Poisonous Materials | 173.132/173.133 | CLASS 6 |
| Infectious Substance | 173.134 | CLASS 6 |
| Class 7 Radioactive Materials | 173.403 | CLASS 7 |
| Class 8 Corrosive Materials | 173.136/173.137 | CLASS 8 |
| Class 9 Miscellaneous Hazardous Material | 173.140/173.141 | CLASS 9 |
| Other Regulated Materials | 173.144 | ORM-D |
| Air Requirements | Part 175 | AIR |
| Highway Carrier Requirements | Part 177 | HWY |
| Specifications for Packaging | Part 178 | PKG |

## 2.2 DEFINITION OF TERMS

There are many terms in the regulations that have specific meanings. Therefore, it is important to know how these terms have been defined by the regulator.

General Definitions – These apply throughout the regulations and are found in Section 171.8.

Specific Definitions – These apply to a specific subject and are found in the section(s) dealing with that subject. For example, Section 173.403 contains the radioactive material definitions.

Review Section 171.8. Locate the definitions for the terms shown in Table 2-2 on the following page, read them carefully, and highlight them in your copy of the regulations for future reference.

**Table 2-2. Important Definitions to Know in Section 171.8**

| | | |
|---|---|---|
| Bulk packaging | Material of trade | Reportable quantity |
| Cargo aircraft only | Material poisonous by inhalation | Research |
| Combination packaging | Mixture | Residue |
| Composite packaging | Movement | Shipping paper |
| Hazardous materials | Nonbulk packaging | Sift-proof packaging |
| Hazardous substance | Overpack | Solution |
| Hazardous waste | Packaging | Specification packaging |
| Hazmat employee | Packing group | Storage incidental to movement |
| Hazmat employer | Person | Strong outside container |
| Limited quantity | Person who offers or offeror | Subsidiary hazard |
| Liquid | Primary hazard | Transportation |
| Loading incidental to movement | Pre-transportation function | Undeclared hazardous material |
| Marine pollutant | Proper shipping name | Unintentional release |

## 2.3 DETERMINING APPLICABLE REQUIREMENTS

For every hazardous material shipment, determinations must be made in order to **identify** (characterize) the material, **classify** the material under the DOT regulations, **contain** (package) the material, **communicate** the hazard, and place any necessary **controls** on the shipment. In this decisionmaking process, the shipper is forced to answer the following questions:

1. Will this shipment be subject to domestic or international regulations?
2. What mode(s) will be utilized?
3. What quantity of material will be in each package/conveyance?
4. What DOT hazard class(es) does my material meet?
5. Is the material a hazardous substance?
6. Is the material a hazardous waste?
7. Is the material a PIH material?
8. Does the material contain asbestos?
9. Does the material contain PCBs?
10. Is the material a marine pollutant?
11. Does the material contain oil?

The answers to these questions will determine how the material is classed under the DOT regulations, how it is packaged, and what communication and control requirements are applied.

## 2.4 THE IDENTIFICATION AND CLASSIFICATION PROCESS

Title 49 CFR Part 173.22(a)(1) requires that persons offering a hazardous material for transport classify and describe the hazardous material in accordance with the regulations. This burden is rightfully placed with the offeror (shipper), as they should be the most knowledgeable about the material and its properties.

Correct identification and classification is the most important function under the regulations because this determination will establish all other requirements for packaging, marking, labeling, placarding, documentation, carrier requirements, and shipment controls. It will also determine what actions are taken by a first responder in the event of an incident during transport.

The classification decision must combine chemistry, physics, regulations, experience, common sense, and good judgment. It will necessarily also require the cooperation and use of personnel with expertise in a number of different areas. It will often require consultation with a number of different sets of regulations, technical references, and sets of analytical data. Consequently, this can be a time-consuming task, and it is essential that adequate time be budgeted to ensure that it can be performed properly.

With technical grade material, classification will generally be less time- and labor-intensive and may be as simple as finding the material listed in the DOT HMT and using the hazard class designated there. With mixtures of two or more hazardous materials (and especially for hazardous waste), this process will require considerably more effort.

### Material Identification

The identification process entails determining the physical and chemical characteristics of the material, as well as determining which sets of regulations will apply to the material. For example, consider a mixture of acids that are corrosive and oxidizers, in an amount per package that causes them to be regulated as a hazardous substance, and are regulated as hazardous waste when they are shipped for disposal. In this case, the acid mixture is a DOT hazardous material, an EPA hazardous waste, and also an EPA/DOT hazardous substance. The mixture meets all of these definitions, and it will be regulated to some extent by all of these agencies. However, when it comes to the classification step, we will see that there will be a single DOT hazard class assigned to this material. The hazard class will dictate the proper shipping name choice, the authorized packaging, and the hazard communication requirements.

*Hazardous Materials*

The DOT has listed a significant number of technical grade chemicals in the HMT at Section 172.101. The materials specifically listed have been evaluated and classed by the DOT, and no further analysis as to the hazardous properties is required by the shipper of these materials. If, however, the material is not specifically listed and/or is a mixture or solution, then it is incumbent on the shipper to determine which of the defining hazard class criteria the material meets.

For example, sodium peroxide is specifically listed in Column 2 of the HMT. Alternatively, a material may not be listed by technical name but may be represented by a chemical group or functional use list. For example, “Ketones, liquid, n.o.s.” (not otherwise specified) and “Dyes, liquid, corrosive, n.o.s.” are listed in the HMT. In each case, the DOT has identified the material as being a hazardous material and has indicated the appropriate hazard class in Column 3 of the HMT. Figure 2-1 on the following page provides the hazard classes and regulatory sections with defining criteria.

*Hazardous Substances*

The DOT defines *hazardous substance* in 49 CFR 171.8. Hazardous substances are materials identified by the EPA that pose a hazard to the environment. These materials are incorporated into the DOT regulations in Appendix A of the HMT. Associated with each material listed is an RQ value. The RQ value for a nonradioactive material is expressed as pounds (lb) or kilograms (kg). For radioactive material, RQ values are expressed in curies (Ci) or terabecquerels (TBq).

For transportation purposes, a hazardous substance is a material specifically listed in Appendix A where the amount in one package equals or exceeds the RQ value. For a nonradioactive mixture or solution (weighing at least 22,680 kg), the table in Section 171.8 should be used. A material that is a hazardous substance but does not meet any DOT hazard class definition for Hazard Classes 1–8 is regulated as a Class 9 material.

**Hazard Classes and Regulatory Sections**

If a material is not listed in the HMT, then the shipper must determine if the material meets the defining criteria of any of the nine DOT hazard classes. The hazard classes and the regulatory sections containing the defining criteria are as follows:

| | | | |
|---|---|---|---|
| 173.50 | Class 1 | | Explosives |
| 173.115 | Class 2 | Divisions 2.1, 2.2, 2.3 | Gases |
| 173.120 | Class 3 | | Flammable Liquids |
| 173.124 | Class 4 | Division 4.1 | Flammable Solid |
| | | Division 4.2 | Spontaneously Combustible Material |
| | | Division 4.3 | Dangerous When Wet |
| 173.127 | Class 5 | Division 5.1 | Oxidizers |
| 173.128 | | Division 5.2 | Organic Peroxide |
| 173.132 | Class 6 | Division 6.1 | Poisonous Material |
| 173.134 | | Division 6.2 | Infectious Substances |
| 173.403 | Class 7 | | Radioactive Material |
| 173.136 | Class 8 | | Corrosive Material |
| 173.140 | Class 9 | | Miscellaneous Hazardous Materials |
| 173.144 | ORM-D | | Other Regulated Material |

These hazard classes are identical under the international regulations, with the exception of Class 3 material under the IMDG Code. The IMDG Code has three divisions of Class 3 material, based on the flash point of the material. The flash point for Class 3 material is defined differently in the IMDG Code and in the ICAO/IATA regulations than it is in 49 CFR.

**Figure 2-1. Hazard classes and regulatory sections with defining criteria**

*Hazardous Waste*

Hazardous waste is regulated by the EPA and includes materials that could have a harmful effect on human health or the environment. Under the EPA regulations, these materials are identified either by being on one of four lists (F, K, P, or U) or by meeting one or more of four characteristics (ignitability, corrosivity, reactivity, and toxicity). A full explanation of how to identify hazardous waste is provided later in this manual. If a material is regulated by the EPA as a hazardous waste but does not meet any of the DOT criteria for Hazard Classes 1–8, then the DOT regulates it as a Class 9 material.

*Poison Inhalation Material*

These materials are defined in 49 CFR 171.8 under "material poisonous by inhalation," and they are specifically called out in the identification process because these materials have additional communication requirements. These materials are generally flammable liquids or gases that are also toxic (poisonous).

*Marine Pollutants*

Marine pollutants are materials that pose an environmental threat if released into waterways. The definition is contained in 49 CFR 171.8, and the materials are listed in Appendix B of the HMT. Certain requirements and exceptions apply based on the concentration, size of the package, and mode of transport. These exceptions are found in 49 CFR 171.4. Unless they meet another DOT Hazard Class 1–8 definition, marine pollutants are regulated as Class 9 materials.

*Oil*

The requirements to ship oil or material containing oil are found in 49 CFR 130. The definitions, exceptions, and requirements for communication, packaging, and spill response plans are found in this subchapter of the regulations. Unless it meets another DOT Hazard Class 1–8 definition, oil and oil-contaminated materials are regulated as Class 9 materials.

*Decision Chart to Navigate Through the Regulations*

Figure 2-2 provides a decision chart that can be used as a checklist to make sure all applicable determinations are made. Shippers should take each section of the chart and make the appropriate determinations as to the mode of transport and what characteristics the material being shipped meets. This will help ensure that all the appropriate regulations are evaluated and addressed prior to shipment.

To use the chart, enter from the top or bottom, as appropriate for domestic or international shipments. This will help determine if the international air or water regulations will be needed in addition to 49 CFR. Work through the interior boxes in any sequence, evaluating the material being shipped against the definitions and requirements found in the referenced regulations in each box. When the process is completed, you should have answered the 11 questions presented earlier in this chapter.

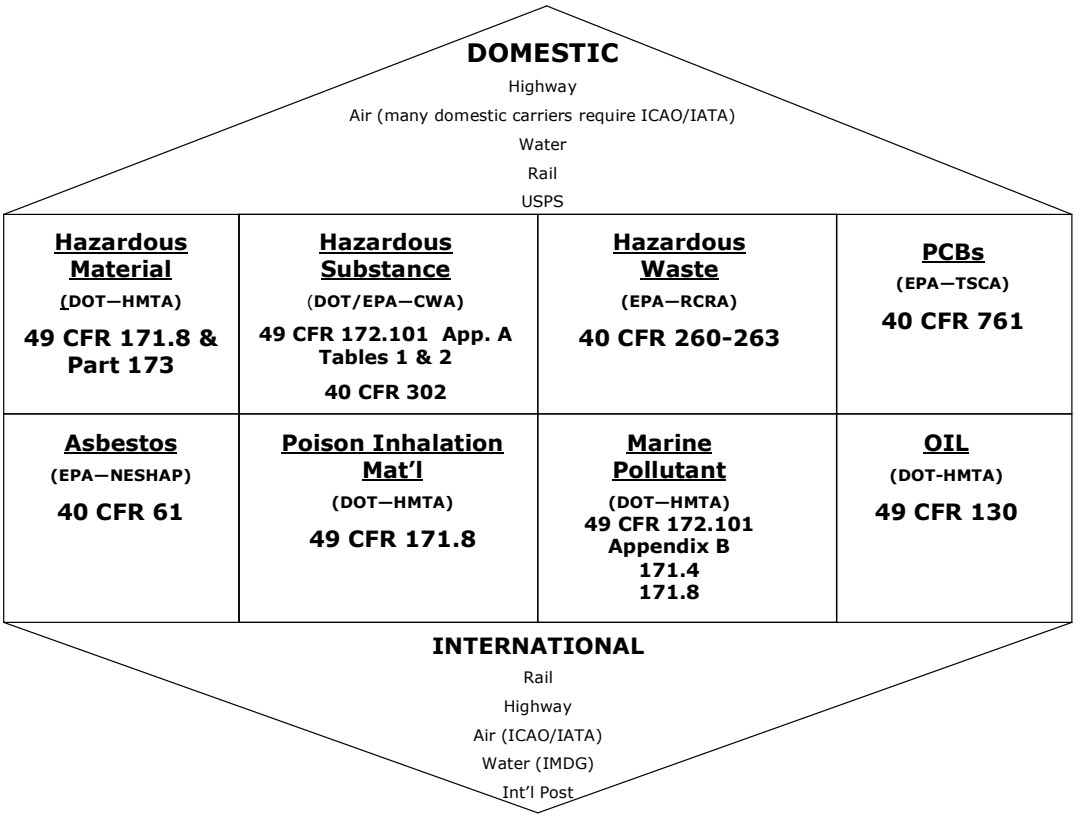



**Figure 2-2. Decision chart to navigate the regulations**

## Material Classification

Hazardous materials are classified according to their chemical and/or physical properties or their relative hazard to health. The DOT has adopted the UN system of identifying hazardous materials by class number. The regulations in 49 CFR generally show both the UN hazard class number and, in parenthesis, the name of that hazard class. For example, under the UN system, flammable liquids are Class 3. This is shown in 49 CFR as "Class 3 (flammable liquid)." Some materials are identified with a Division number. For example, compressed gas could be Division 2.1 (flammable gas), Division 2.2 (nonflammable gas), or Division 2.3 (poisonous gas).

Most hazardous materials are assigned to a packing group according to the degree of danger. There are three packing groups: I, II, and III. Packing Group I packages are for the greatest danger, Packing Group II for medium danger, and Packing Group III for minor danger. Materials in the same hazard class may require different packing groups. For example, Class 3 (flammable liquids) may be assigned to Packing Group I, II, or III, depending on the characteristics of the material, such as the flash point and boiling point. Packing groups are not assigned to Class 2 (gases), Class 7 (radioactive) material, or material classed as ORM. Section 173.2 contains a table listing the hazard classes, their names, and those sections which contain definitions for classifying material.

If a material is one of the specifically listed chemicals in the HMT, then the DOT has already determined the hazard class and the shipper can rely on the class listed in Column 3. In other cases, analytical data or Material Safety Data Sheet information may be used in conjunction with the hazard class definitions in Section 171.8 and 49 CFR 173 to determine the hazard class. For mixtures with multiple hazards, Section 173.2a must be used to make the hazard class determination.

Frequently, a material has properties which meet the definition of more than one hazard class. If the material is not specifically shown in Column 2 of the HMT, the shipper must classify the material according to the "Precedence of Hazard Table" in Section 173.2a. This table determines which is the primary hazard class (or division) and, therefore, how the material is classed. See Figure 2-3 for an example of material classification.

**NOTE: Class 9 will never be a primary or subsidiary hazard when Class 9 material is mixed with materials meeting Class 1-8 criteria. See the definition of Class 9 in Section 173.140.**

**Classification Example**

You have 10 gallons of dimethylethanolamine needed for a research project. Consulting the HMT, you find that this material is not listed. It is also not listed in the RQ tables or in the list of marine pollutants. It is not being shipped for disposal, so we will not consider the RCRA waste regulations. We now have to determine if it meets any of the defining criteria for one or more of the DOT hazard classes.

We are able to obtain the Material Safety Data Sheet for this material, and it indicates that this material is:

- Liquid, clear to slightly yellow in color
- Boiling point is 139°C
- Specific gravity is 0.8866
- Material causes full thickness destruction of skin tissue after 15 minutes of exposure
- Flash point is 40.5°C
- Melting point is –59°C
- There is no reference to toxicity

The DOT hazard class definitions are provided in Part 173, Subparts C, D, and I. Using this information and the process of elimination, we can determine which hazard classes are applicable to this material. Based on the Material Safety Data Sheet information, Class 3 and Class 8 are the logical choices to pursue.

Using the criteria for Class 3 (flammable) material in Section 173.120 and the packing group criteria in Section 173.121, we determine this material meets the criteria for Class 3, Packing Group III.

Using the criteria for Class 8 (corrosive) material in Section 173.136 and the packing croup criteria in Section 173.137, we determine that this material meets the criteria for Class 8, Packing Group II.

We have a material that is both flammable and corrosive. Since only one hazard class is assigned for a material, we must use the precedence table in Section 173.2a. From Section 173.2a, we determine that this material should be classed as Class 8, Packing Group II, with the subsidiary hazard of Class 3.

**Figure 2-3. Classification example**

The primary hazard class (or division) is shown on the shipping papers and used to determine vehicle placarding and other operating requirements for the carrier. Other hazards that a material may possess are called *subsidiary hazards* and are communicated through additional shipping paper entries and/or hazard warning labels on the packages. As an example, "Crotonaldehyde, stabilized" is a material that is Division 6.1 (poison), Packing Group I, and also Class 3 (flammable liquid). This material has a primary hazard of Division 6.1 and a subsidiary hazard of Class 3. In addition, it will be identified on the shipping papers as a PIH material.

Within DOE, it is possible for Class 7 material to meet one or more other DOT hazard class definitions. In addition, the radioactive material may also be regulated as a hazardous substance, hazardous waste, or marine pollutant. Consequently, these types of shipments can be very complex, and care must be taken to class the material properly to ensure all regulatory requirements are met.

### Identification and Classification Using the Air and Water Requirements

The identification and classification process under the ICAO/IATA is the same as that in 49 CFR. In the IATA regulations, see Section 3 for the hazard class definitions and Section 3.10 for the material classification and the precedence table. The comparable sections in the IMDG Code are found in Part 2.

## 2.5 HAZARDOUS MATERIALS TABLE—ROADMAP INTO THE REGULATIONS

The heart of the HMR is the HMT in Section 172.101. In general terms, the HMT contains a list of those materials which have been designated by the DOT as hazardous materials for the purpose of being transported in commerce, and it gives specific information and/or references to the following information:

§172.101 Hazardous Materials Table

| Sym-bols | Hazardous materials descriptions and proper shipping names | Hazard class or division | Identifica-tion Numbers | PG | Label Codes | Special provisions (§172.102) | (8) Packaging (§173.***) | | | (9) Quantity limitations | | (10) Vessel stowage | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Excep-tions | Non-bulk | Bulk | Passenger aircraft/rail | Cargo air-craft only | Location | Other |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8A) | (8B) | (8C) | (9A) | (9B) | (10A) | (10B) |
| | Acetaldehyde | 3 | UN1089 | I | 3 | A3, B16,T11, TP2, TP7 | None | 201 | 243 | Forbidden | 30 L | E | |
| A | Acetaldehyde ammonia | 9 | UN1841 | III | 9 | IP8, IP6 | 155 | 204 | 240 | 200 kg | 200 kg | A | 34 |
| | Acetaldehyde oxime | 3 | UN2332 | III | 3 | B1, IB3, T4, TP1 | 150 | 203 | 242 | 60 L | 220 L | A | |

- Mode or modes by which regulated, Column 1
- Proper shipping name, Column 2
- Hazard class or division, Column 3
- UN Identification (UN ID) number, Column 4
- Packing group, Column 5
- Hazardous material label(s) required, Column 6
- Special provisions, Column 7
- Packaging requirements, Column 8
- Net quantity limitations per package for shipments by passenger-carrying aircraft, railcar, or cargo-only aircraft, Column 9
- Special requirements for water shipments, Column 10

### When is the material regulated? (HMT Column 1) [172.101(b)]

Many of the materials listed in the HMT are not always regulated as hazardous materials. For example, "paint" may be a flammable liquid. However, if it is a water-based paint and, therefore, not flammable, then it is not subject to the HMR. Also, some materials are regulated when shipped by air and water, but they are not subject to the regulations when shipped by highway or rail.

Section 172.101(b) discusses Column 1 of the HMT. This section contains information specifying the mode or modes by which a hazardous material is regulated. Column 1 uses “A,” "W," or no symbol to designate these. Column 1 also contains the symbols “+,” “D,” “G,” and “I,” and the meaning of each symbol is explained in Section 172.101(b).

The symbol "A" in Column 1 indicates that the hazardous material described in Column 2 is subject to the regulations only when offered or intended for transport by air, unless the material is also a hazardous substance or hazardous waste, when it is regulated by all modes. Refer to the entry for "Calcium oxide" in Column 2 of the HMT. Column 1 contains the symbol "A." Calcium oxide is regulated only when transported by air unless it is also a hazardous substance or hazardous waste.

The symbol "W" in Column 1 indicates that the hazardous material described in Column 2 is subject to the regulations only when offered or intended for transport by water, unless the material is also a hazardous substance or hazardous waste, when it is regulated by all modes. Refer to the entry for "Cotton" in Column 2 of the HMT. Column 1 contains the symbol "W." Cotton is regulated only when transported by water, unless it is also a hazardous substance or hazardous waste.

If neither an "A" nor a "W" is listed in Column 1, the material listed in Column 2 is regulated by all modes of transportation. Refer to the entries for "Acetone" and "Allyl alcohol" in Column 2 of the HMT. Both of these hazardous materials are regulated by all modes of transportation.

If a (+) appears in Column 1, it means the hazardous material is listed in Column 2, its hazard class shown in Column 3, and the packing group shown in Column 5 must be used for that entry without regard to whether the material meets the definition of the hazard class or packing group.

The materials listed in Column 2 may or may not be hazardous materials. To make this determination, the shipper should compare the chemical characteristics of the material against those listed in the definition section of Part 173 for the hazard class listed in Column 3. If the material’s characteristics do not meet the definition of the hazard class listed or the definition of any other hazardous material, then the material is not regulated by 49 CFR as a hazardous material.

***NOTE: It is the shipper's responsibility to ensure that all hazardous materials are properly identified and classified prior to offering them for shipment. (See Section 171.2.) It is, therefore, necessary for a shipper to compare the chemical characteristics of the material against the definition sections of all the classes of hazardous materials to ensure that the material does not meet any of the hazard classifications specified. For each hazard class, Section 171.8 provides the appropriate section reference within 49 CFR where the definition for the hazard class can be found.***

Refer to the entry "Boron trifluoride" in Column 2 of the HMT. There is no (+) in Column 1. If it is a hazardous material, by what mode is it regulated? The answer is “all modes” because there is no "A" or "W" in Column 1. Column 3 indicates that the hazard division is "2.3 (poison gas)." Reference to Section 171.8 for the definition of Class 2 indicates that the definition is found in Section 173.115. If a comparison of the chemical characteristics of the material against the characteristics listed in the definition section indicates the material meets the definition, then it is a hazardous material and must be offered and transported in accordance with 49 CFR using the shipping name contained in Column 2 of the HMT.

See Figure 2-4 on the following page for an example of the thought processes for determining the applicable regulations for PCBs. This example shows the importance of addressing each of the 11 questions and/or using the decision chart referenced earlier in this chapter. As demonstrated in the example, the requirements for packaging and transporting PCBs vary greatly depending on how the questions related to transport mode and material quantity are answered.

**When are PCBs regulated?**

Find the entry for "Polychlorinated Biphenyls" in the HMT. There is an "A" and a "W" in Column 1, and Column 2 states "see Polychlorinated Biphenyls." Note that there are no entries in the rest of the columns. Therefore, all information about shipping PCBs will be found with the "Polychlorinated Biphenyls" entry.

The entry for PCBs does not include an "A" or a "W" in Column 1. Based on the entries for "PCBs, liquid" and "PCBs, solid," it would appear that the material is regulated by all modes.

However, we must pay attention to the special provisions listed in Column 7. Specifically, we need to look at the reference to Special Provision 140. Special provisions are included behind the appendices of the HMT. Special Provision 140 states that PCBs are not regulated as a hazardous material unless they are a hazardous substance or a marine pollutant. If they are a hazardous substance, they are regulated by all modes.

Using Appendix A, Table 1, of the HMT, we determine that PCBs are a hazardous substance when there are 0.454 kg (1 lb) or more in a package.

PCBs are listed in the marine pollutant table (Appendix B of the HMT) as a severe marine pollutant. Section 171.4 states that marine pollutants are regulated only by water unless they are transported in bulk packaging by highway, rail, or air.

If we offer our PCBs by air, most domestic air carriers require compliance with the ICAO/IATA regulations. Looking up PCBs in the IATA regulations, we are referred to Special Provision A11, which states that PCBs are not regulated by air unless they are in concentrations ≥50 parts per million (ppm). There is a similar provision in the water regulations (IMDG Code).

Consequently, depending on our mode of transport, the packaging, and the quantity of PCBs, our material could be (a) not regulated, (b) regulated as a Class 9 material and a hazardous substance, or (c) regulated as a Class 9 material, hazardous substance, and marine pollutant.

**Figure 2-4. When are PCBs regulated?**

## Proper Shipping Names (HMT Column 2) [172.101(c)]

For technical grade material, the HMT may specifically list that material by name. For example, find the entry for "Blue asbestos" in the HMT. Section 172.101(c)(1)–(9) should be reviewed for the rules regarding format and the modifications that are allowed for the proper shipping name entries used on shipping documentation.

Find the proper shipping name "Blue asbestos." Notice the entry "Blue asbestos or Brown asbestos." The italicized "or" means that any of the terms in the sequence may be used as part of the proper shipping name, as appropriate.

§172.101 HAZARDOUS MATERIALS TABLE

| Symbols (1) | Hazardous materials descriptions and proper shipping names (2) | Hazard class or Division (3) | Identification Numbers (4) | PG (5) | Label Codes (6) |
|---|---|---|---|---|---|
| | *Bleaching powder, see* Calcium hypochlorite mixtures, *etc.* | ..... | | | ..... |
| I | Blue asbestos *(Crocidolite) or* Brown asbestos *(amosite, mysorite).* | 9 | UN2212 | II | 9 ..... |
| | Bombs, photo-flash ..... | 1.1F | UN0037 | II | 1.1F ... |
| | Bombs, photo-flash ..... | 1.1D | UN0038 | II | 1.1D ... |
| | Bombs, photo-flash ..... | 1.2G | UN0039 | II | 1.2G ... |
| | Bombs, photo-flash ..... | 1.3G | UN0299 | II | 1.3G ... |

Proper shipping names may be specific, such as propane, or they may refer to a group of materials having the same hazard but which are not specifically named. These materials are identified by one of the all-inclusive phrases or abbreviations such as n.o.s., n.o.i. (not otherwise indexed), or n.o.i.b.n. (not otherwise indexed by name). There is a generic grouping for most hazard classes (e.g., "flammable liquid, n.o.s.," "corrosive solid, acidic, inorganic, n.o.s.").

Generic proper shipping names may also be descriptive of the chemical family or end use. “Alcohols, n.o.s.” is an example of a chemical family name. “Compounds, cleaning liquid” is an end-use generic proper shipping name. Proper shipping names are assigned by the regulations for uniformity and are listed in Column 2 of the HMT, which is provided in Section 172.101.

The proper shipping name generally appears on the shipping papers (Section 172.202), is marked on the package (Section 172.301), and may be entered on certain other documents. Although Column 2 contains entries in both Roman type and italics, only the entries shown in Roman type may be used as proper shipping names (Section 172.101(c)).

Refer to the entry in Column 2 of the HMT for "Benzyl chloride *unstabilized*." The proper shipping name is the description in Roman type, "Benzyl chloride." Although the word in italics (unstabilized) is not required as part of the shipping name, it may be included on the shipping papers in addition to the proper shipping name indicated by Roman type (e.g., Benzyl chloride, unstabilized).

The shipper must use the proper shipping name in Column 2 of the HMT that most appropriately describes the hazardous material being shipped. A shipper transporting a container of gasoline, Class 3 (flammable liquid), must use the proper shipping name "Gasoline," not "Flammable liquid, n.o.s." “Gasoline is” the shipping name that most appropriately describes the commodity. (See Section 172.101(c)(12).)

When one entry references another entry by the use of the word *See*, then either name may be used as the proper shipping name, provided both are in Roman type. (See Section 172.101(c)(5).) Refer to the entry in Column 2 of the HMT for “Isobutyl alcohol.” Although it references another entry (isobutanol), either one may be used as the proper shipping name because both are in Roman type. Although either name may be used as the proper shipping name, reference <u>must</u> be made to the entry for “Isobutanol” to get the information found in Columns 1 and 3-10 of the HMT. (See Section 172.101.)

When choosing proper shipping names, it is important to determine the properties of the material and where those properties fit into the regulations. A material may be changed by diluting or mixing to fit a particular need. This means that the shipping description may also change. The table in Section 172.101 is not a list of chemicals; it is a list of proper shipping names. When the chemical or material is not technical grade or has been modified, the properties may not match the hazard class shown in the HMT for the associated proper shipping name entry. In this situation, another proper shipping name must be selected that matches the appropriate hazard class of the material.

### Mixtures and Solutions

When a hazardous material and a nonhazardous material are combined, the proper shipping name must be the proper shipping name plus the qualifier *mixture* or *solution*, unless the other information in the description doesn’t match (e.g., different physical form, hazard, or emergency protocols) or if it is excepted. See Section 171.101(c)(10)(i).

Acetone, a hazardous material + water, a non-hazardous material = Acetone mixture or Acetone solution.

Although many materials are specifically listed in the HMT, there are times when the shipper must select a proper shipping name for:

- A material listed in the HMT but mixed with a nonhazardous material.
- A material not listed in the HMT.
- A material that is a mixture of two or more hazardous materials.

- A material that is specifically listed but which no longer meets the hazard class, packing group, or subsidiary hazard(s) listed in the HMT.

### Hazardous Material Not Specifically Listed by Name in the HMT

Before a proper shipping name can be selected for a material that is not listed in the HMT, its hazard class and packing group must be determined. For a material meeting more than one hazard class, the packing group of each class must be determined. Definitions for each hazard class and packing group are found in Part 173. Section 173.2 provides an index to the sections where the hazard classes are defined.

Section 172.101(c)(12)(iii) provides some guidance for selecting the proper shipping name for a material that meets more than one hazard class. This section directs the reader to Section 173.2a to determine the primary class of the material. Each of the other classes that the material meets is known as a subsidiary class or hazard.

After the primary hazard class is determined, the shipping name for the material must be determined. Section 172.101(c)(12)(ii) provides some guidance:

> ". . . selection of proper shipping name shall be made from the generic or n.o.s. descriptions corresponding to the specific (i.e., primary) hazard class, packing group, or subsidiary hazard, if any, for the material. The name that most appropriately describes the material shall be used; e.g., an alcohol shall be described as 'Alcohol, n.o.s.' rather than 'Flammable liquid, n.o.s.' Some mixtures may be more appropriately described according to their application . . ."

The HMT has numerous generic shipping names. It is important to select the name that most appropriately describes the material (i.e., a name that fits the primary hazard class and packing group). It also is important to note that the hazard class or packing group of a name in the table cannot be changed. If a shipping name fits the material but the hazard class, packing group, or subsidiary hazard(s) do not correspond, a different shipping name must be selected.

The above guidance is also appropriate for determining the proper shipping description for a mixture of two or more hazardous materials. However, if the material is the mixture of a material specifically listed in the HMT and a nonhazardous material, Section 172.101(c)(10) requires that the material be described using its listed proper shipping name and the qualifying words *mixture* or *solution* (e.g., acetone solution), <u>unless</u>:

- The packaging specified is inappropriate for the physical form of the material (e.g., packaging for a solid versus a liquid product).
- The proper shipping name applies only to the pure product.
- The hazard class, packing group, or subsidiary hazard of the mixture is different from that specified.
- There is significant change in any emergency response measures involving the mixture.
- The material is identified in Column 7 of Section 172.101 as a PIH (under Special Provisions 1–6); however, it no longer meets that definition or falls into a different hazard class.
- The material can be described by a proper shipping name describing its intended end use (e.g., "coating solution or compound, cleaning fluid").

If one of these conditions is met, then selection of the shipping description must be made in the same fashion as a material not specifically listed in the HMT.

### Hazardous Waste Shipments and Samples Being Shipped for Analysis [172.101(c)(11)]

If a technical grade material also meets the definition of a hazardous waste (Section 171.8), then Section 172.101(c)(9) states that the word *Waste* must precede the proper shipping name (e.g., "Waste Acetone").

For nontechnical grade material, two proper shipping names are authorized for domestic shipments: "Hazardous waste, liquid, n.o.s." and "Hazardous waste, solid, n.o.s."

Sometimes the hazard class for samples of materials cannot be determined unless they are shipped for further analysis. Section 172.101(c)(11) provides that sample material, where the hazard class is uncertain and must be determined by testing, may be assigned a tentative proper shipping name, hazard class, UN ID number, and packing group based on the following:

- Defining criteria.
- Hazard precedence in Section 173.2a.
- Shipper's knowledge of the material.

The word *sample* must be shown in association with the basic description on the shipping papers.

***NOTE: Section 172.101(c)(11) and the sample provisions do not apply to Class 7 material, as the presence of radioactivity is readily determined by field instrumentation and does not require testing. Samples of radioactive material are shipped based on their categorization as excepted quantity, Type A, Type B, etc.***

### Hazard Class (HMT Column 3) [172.101(d)]

Column 3 of the HMT contains the assigned hazard class or division number of the proper shipping name as it must appear on the shipping papers. When reference to Column 3 indicates a class entry of *Forbidden*, that material may not be offered or accepted for transportation. (See Section 172.101(d)(1).) Material that is not specifically identified in the HMT, Section 172.101, and which has more than one hazard as described in Part 173 must be classed according to Section 173.2a.

**HMT - Column 3**

A description of each hazard class and the section reference for class definitions appear in 173.2 of the HMR.

§172.101 HAZARDOUS MATERIALS TABLE

| Symbols (1) | Hazardous materials descriptions and proper shipping names (2) | Hazard class or Division (3) | Identification Numbers (4) | PG (5) | Label Codes (6) |
|---|---|---|---|---|---|
| | Ammonium arsenate | 6.1 | UN1546 | II | 6.1 |
| | *Ammonium azide* | Forbidden | | | |
| | *Ammonium bifluoride, solid, see* Ammonium hydrogen difluoride, solid. | | | | |
| | *Ammonium bifluoride solution, see* Ammonium hydrogen difluoride, solution. | | | | |
| | *Ammonium bromate* | Forbidden | | | |
| | *Ammonium chlorate* | Forbidden | | | |
| | Ammonium dichromate | 5.1 | UN1439 | II | 5.1 |
| | Ammonium dinitro-o-cresolate | 6.1 | UN1843 | II | 6.1 |

### UN ID Number (HMT Column 4) [172.101(e)]

Column 4 of the HMT contains the UN ID number for the material. This number is keyed to emergency response information, such as the DOT *Emergency Response Guide Book*, to assist fire, police, and other responders during an incident or accident. When completing the shipping descriptions on shipping papers, the UN ID number is shown first in the sequence for the basic description.

**HMT - Column 4**

Column 4 of the HMT lists the 4 digit identification number assigned to each proper shipping name.

§172.101 HAZARDOUS MATERIALS TABLE

| Symbols (1) | Hazardous materials descriptions and proper shipping names (2) | Hazard class or Division (3) | Identification Numbers (4) | PG (5) | Label Codes (6) |
|---|---|---|---|---|---|
| | *Accellerene, see* p-Nitrosodimethylaniline. | | | | |
| | *Accumulators, electric, see* Batteries, wet *etc.* | | | | |
| D | Accumulators, pressurized, pneumatic *or* hydraulic (*containing non-flammable gas.* | 2.2 | NA1956 | | 2.2 |
| | Acetal | 3 | UN1088 | II | 3 |
| | Acetaldehyde | 3 | UN1089 | I | 3 |

### Packing Group (HMT Column 5) [172.101(f)]

Column 5 of the HMT contains one or more packing groups assigned to a material. If more than one packing group is listed in Column 5, the shipper must go to the appropriate regulations to select the packing group based on the criteria for each hazard class or division. No packing groups are assigned to Class 2 (compressed gases), Class 7 (radioactive material), or ORM-D.

**HMT - Column 5**

Packing Groups

- PG I = Great Danger
- PG II = Medium Danger
- PG III = Minor Danger

§172.101 HAZARDOUS MATERIALS TABLE

| Symbols (1) | Hazardous materials descriptions and proper shipping names (2) | Hazard class or Division (3) | Identification Numbers (4) | PG (5) | Label Codes (6) |
|---|---|---|---|---|---|
| | Acetal | 3 | UN1088 | II | 3 |
| | Acetaldehyde | 3 | UN1089 | I | 3 |
| A | Acetaldehyde ammonia | 9 | UN1841 | III | 9 |
| | Acetaldehyde oxime | 3 | UN2332 | III | 3 |
| | Acetic acid, glacial *or* Acetic acid solution, *with more than 80 percent* | 8 | UN2789 | II | 8, 3 |

### Basic Description

The basic description referenced in the shipping paper requirements is comprised of the hazard class, proper shipping name, UN ID number, and packing group. (See Sections 172.201(a)(1)(ii) and 172.202(a)(1)–(4).) See Figure 2-5 below for an example. This information comes from Columns 2, 3, 4, and 5 of the HMT.

*NOTE: Class 7 material does not have a packing group.*

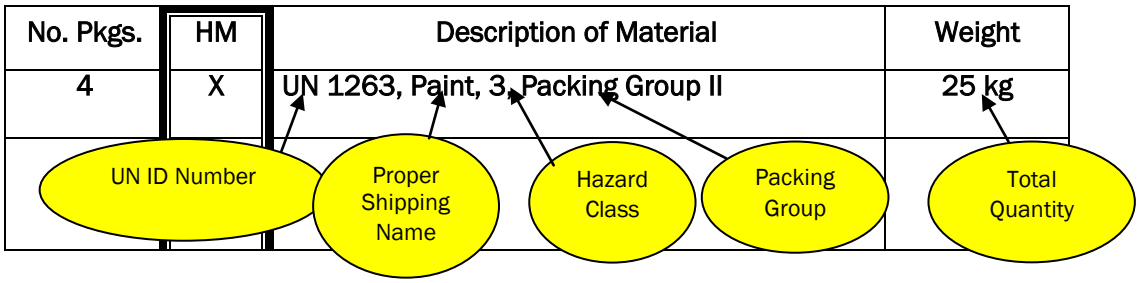



**Figure 2-5. Example of a basic description**

Section 172.202(b) requires the basic description to be written with the UN ID number listed first. The old sequence, prior to January 1, 2008, was proper shipping name, hazard class, UN ID number, and packing group.

*NOTE: The new basic description sequence became mandatory on January 1, 2008, under HM-215 I (published as a final rule on December 29, 2006). However, except for air and water shipments, Section 171.14(e) permissively allows the old sequence to be used until January 1, 2013.*

Entries on shipping documents prepared under the ICAO/IATA and the IMDG Code must have the basic description in the following sequence: UN ID number, proper shipping name, hazard class or division, and packing group. In addition, the net quantity of hazardous material per package must be shown on the shipper's declaration for air shipments.

### Labels (HMT Column 6) [172.101(g)]

Column 6 of the HMT shows the required labeling, unless it is excepted elsewhere in the regulations. Labeling requirements are provided in Section 172.400, et al.

§172.101 HAZARDOUS MATERIALS TABLE

| Symbols (1) | Hazardous materials descriptions and proper shipping names (2) | Hazard class or Division (3) | Identification Numbers (4) | PG (5) | Label Codes (6) | Special provisions (7) |
|---|---|---|---|---|---|---|
| G | Alcohols, flammable, toxic, n.o.s | 3 | UN1986 | I | 3, 6.1 | T8, T31 |
| | | | | II | 3, 6.1 | T8, T31 |
| | | | | III | 3, 6.1 | B1, T8, T31 |
| | Aldehydes, n.o.s | 3 | UN1989 | I | 3 | T8, T31 |
| | | | | II | 3 | T8, T31 |
| | | | | III | 3 | B1, T7, T30 |
| G | Aldehydes, flammable, toxic, n.o.s | 3 | UN1988 | I | 3, 6.1 | T8, T31 |
| | | | | II | 3, 6.1 | T8, T31 |
| | | | | III | 3, 6.1 | B1, T8, T31 |
| | Aldol | 6.1 | UN2839 | II | 6.1 | T8 |
| D | Aldrin, *liquid* | 6.1 | NA2762 | II | 6.1 | |
| D | Aldrin, *solid* | 6.1 | NA2761 | II | 6.1 | |
| G | Alkali metal alcoholates, self-heating, corrosive, n.o.s. | 4.2 | UN3206 | II | 4.2, 8 | 64 |
| | | | | III | 4.2, 8 | 64 |

### Special Provisions (HMT Column 7) [172.101(h) and 172.102]

The special provisions listed in Column 7 of the HMT must always be considered. Special provisions may refer to communicating certain hazards, packaging provisions, prohibitions, exceptions from requirements for particular quantities, and requirements or prohibitions for certain modes of transportation. Also, these provisions may affect package marking, labeling, shipping paper entries, placarding, emergency response information, and modal operating requirements. Column 7 is coded to Section 172.102. By using the numeric and alphanumeric codes, the shipper can determine the specific relationship of the HMR to the particular hazardous material.

§172.101 HAZARDOUS MATERIALS TABLE—Continued

| Hazard class or Division (3) | Identification Numbers (4) | PG (5) | Label Codes (6) | Special provisions (7) | (8) Packaging (§173.***) Exceptions (8A) | Non-bulk (8B) | Bulk (8C) |
|---|---|---|---|---|---|---|---|
| 3 | UN3065 | II | 3 | 24, B1, T1 | 150 | 202 | 242 |
| | | III | 3 | 24, B1, N11, T1 | 150 | 203 | 242 |
| 3 | UN1987 | I | 3 | T8, T31 | None | 201 | 243 |
| | | II | 3 | T8, T31 | 150 | 202 | 242 |
| | | III | 3 | B1, T7, T30 | 150 | 203 | 242 |
| 3 | UN1986 | I | 3, 6.1 | T8, T31 | None | 201 | 243 |
| | | II | 3, 6.1 | T8, T31 | None | 202 | 243 |

Transported By:
A - Air
H - Highway
R - Rail
W - Water

Transported In:
B - Bulk Packaging
N - Non-Bulk Packaging
T - Intermodal (IM) Portable Tanks

Review the entry for "White asbestos" in the HMT. Note that "156" is referenced in Column 7. Locate Special Provision 156. It states that asbestos is not regulated by the DOT as a hazardous material if it is fixed in a binder material or contained in a manufactured product.

Find "Asbestos" in Appendix A of the HMT. The RQ value is 1 lb. However, note that "¢¢" appears after the entry. This refers to a footnote to the table which states that the RQ applies to friable forms only. Therefore, asbestos is not regulated as a hazardous substance or a hazardous material unless it is in a friable form.

### Packaging (HMT Column 8) [172.101(i)]

Column 8 lists the sections on the types of packaging that are authorized for the material. Except for small-quantity shipments in Section 173.4, a packaging section can be used only if it is referred to in the HMT. A full discussion of packaging is provided later in this manual.
Column 8A lists the section in the regulations that covers exceptions to the packaging requirements. If *None* is shown in Column 8A, then no exceptions are authorized and the packaging sections

§172.101 HAZARDOUS MATERIALS TABLE

| Identification Numbers (4) | PG (5) | Label Codes (6) | Special provisions (7) | (8) Packaging (§173.***) Exceptions (8A) | Non-bulk (8B) | Bulk (8C) | Quantity Passenger aircraft/rail (9A) |
|---|---|---|---|---|---|---|---|
| UN3065 | II | 3 | 24, B1, T1 | 150 | 202 | 242 | 5 L |
| | III | 3 | 24, B1, N11, T1 | 150 | 203 | 242 | 60 L |
| UN1987 | I | 3 | T8, T31 | None | 201 | 243 | 1 L |

referenced in Columns 8B or 8C must be used. Column 8B lists the packaging section(s) that must be used for nonbulk shipments, and Column 8C lists the bulk packaging sections.

### Quantity Limitations (HMT Column 9) [172.101(j)]

The quantity limits for material offered by passenger air and rail and for cargo aircraft are shown in Column 9. If *Forbidden* is shown, it means the material may not be offered for transportation or transported in that mode.

§172.101 HAZARDOUS MATERIALS TABLE

| (8) Packaging (§173.***) | | | (9) Quantity limitations | | (10) Vessel stowage | |
|---|---|---|---|---|---|---|
| Exceptions (8A) | Nonbulk (8B) | Bulk (8C) | Passenger aircraft/rail (9A) | Cargo aircraft only (9B) | Location (10A) | Other (10B) |
| 150 ..... | 203 .... | 242 .... | 60 L | 220 L | A | |
| None .... | 201 .... | 243 .... | 1 L | 30 L | E | |
| 150 ..... | 202 .... | 242 .... | 5 L | 60 L | B | |
| 150 ..... | 203 .... | 242 .... | 60 L | 220 L | A | |
| None .... | 201 .... | 243 .... | Forbidden | 30 L | E | 40 |
| None .... | 202 .... | 243 .... | 1 L | 60 L | B | 40 |
| None .... | 203 .... | 242 .... | 60 L | 220 L | A | |
| None .... | 201 .... | 243 .... | 1 L | 30 L | E | |
| 150 ..... | 202 .... | 242 .... | 5 L | 60 L | B | |

The limits in Column 9 of the HMT can be more restrictive than what is allowed for air shipments under the ICAO/IATA regulations. Title 49 CFR Part 171.22(e) and USG 02 in the IATA regulations stipulate that material which is identified in the HMT under Column 9A as forbidden cannot be offered by passenger aircraft, regardless of the entry in the "List of Dangerous Goods" in the IATA regulations. While there a great deal of consistency between the entries in the HMT and the ICAO/IATA "List of Dangerous Goods," shippers should check both entries before offering material for transport by air.

## 2.6 LIST OF DANGEROUS GOODS IN THE AIR AND WATER REGULATIONS

Use of the ICAO regulations is authorized in Sections 171.22, 171.23, and 171.24. You should read and familiarize yourself with the requirements in this section. The IATA *Dangerous Goods Regulations* are published by air carriers, and they reprint the ICAO regulations and add additional requirements imposed by the carriers. Most domestic air carriers require compliance with the IATA requirements for both international and domestic air shipments.

The ICAO/IATA regulations include a table that is comparable to the HMT in 49 CFR. This table, entitled the "List of Dangerous Goods," is located in Section 4 of the IATA regulations. The information in this table is displayed as follows:

Column A: UN ID number
Column B: Proper Shipping Name
Column C: Hazard Class/Division
Column D: Subsidiary Risk
Column E: Hazard Label
Column F: Packing Group
Column G: Packaging Instructions (Limited Quantity by Passenger/Cargo Air)
Column H: Maximum Net Quantity/Package (Limited Quantity by Passenger/Cargo Air)
Column I: Packaging Instructions (Passenger/Cargo Air)
Column J: Maximum Net Quantity/Package (Passenger/Cargo Air)
Column K: Packaging Instructions (Cargo Air Only)
Column L: Maximum Net Quantity/Package (Cargo Air Only)
Column M: Special Provisions
Column N: Emergency Response Guidebook Code

The special provisions are located after the "List of Dangerous Goods." Determinations for hazardous substances, hazardous waste, and marine pollutants must be made in accordance with the DOT regulations, as these terms are not defined in the international regulations. See 49 CFR 171.23 and the state variations for the United States, USG 4, in Section 2 of the IATA regulations.

Part 3, Chapter 3.2, of the IMDG Code contains a table that is comparable to the HMT, and it is entitled "Dangerous Goods List." The comparable entries to the HMT are as follows:

Column 1: UN ID number
Column 2: Proper Shipping Name
Column 3: Hazard Class/Division
Column 4: Subsidiary Risk
Column 5: Packing Group
Column 6: Special Provisions
Column 7: Limited Quantities
Column 8: Packaging Instructions (nonbulk packaging)
Column 9: Packaging Provisions (nonbulk packaging)
Column 10–11: Intermediate Bulk Container Packaging
Column 12–14: Portable Tanks and Bulk Containers

## 2.7 HAZARDOUS SUBSTANCES [SECTION 172.101, APPENDIX A, TABLES 1 AND 2]

At some point in the material identification process, we must determine if the material is a hazardous substance. The definition for *hazardous substance* is found in Section 171.8. To determine if a material is a hazardous substance, use Appendix A of Section 172.101, which follows the HMT. Appendix A is a list of materials and includes the RQ amount in the far right-hand column.

A material is a hazardous substance if it is listed in Appendix A and there is at least an RQ amount of that material in a single package. If the material is mixture or solution, then it must be in a concentration by weight that equals or exceeds the concentration shown in the table in Section 171.8. From a practical standpoint, the only time a mixture or solution will not meet this third criterion is when the material in a package weighs at least 22,680 kg (50,000 lb).

TABLE 1 TO APPENDIX A.–HAZARDOUS SUBSTANCES OTHER THAN RADIONUCLIDES

| Hazardous substance | Reportable quantity (RQ) pounds (kilo grams) |
|---|---|
| Acetic acid, lead (2+) salt | 10 (4.54) |
| Acetic acid, thallium (I+) salt | 1000 (454) |
| Acetic anhydride | 5000 (2270) |
| Acetone | 5000 (2270) |
| Acetone cyanohydrin | 10 (4.54) |
| Acetonitrile | 5000 (2270) |
| Acetophenone | 5000 (2270) |
| 2-Acetylaminofluorene | 1 (0.454) |

Appendix A contains two tables. Table 1 lists the nonradioactive materials, and Table 2 lists the radionuclides.

TABLE 2.— RADIONUCLIDES

| (1)–Radionuclide | (2)–Atomic Number | (3)–Reportable Quantity (RQ) Ci(TBq) |
|---|---|---|
| Actinium - 224 | 89 | 100 (3.7) |
| Actinium - 225 | 89 | 1 (.037) |
| Actinium - 226 | 89 | 10 (.37) |
| Actinium - 227 | 89 | 0.001 (.000037) |
| Actinium - 228 | 89 | 10 (.37) |
| Aluminum-26 | 13 | 10 (.37) |
| Americum - 237 | 95 | 1000 (37) |
| Americum - 238 | 95 | 100 (3.7) |

Find the entry for "Toluene" in Table 1 of Appendix A. It has an RQ of 454 kg (1000 lb). If a shipper puts 1000 lb or more of toluene in a single package, the material then becomes a hazardous substance in addition to being a hazardous material. If the shipper puts less than 1000 lb of toluene in a package, the material would not be a hazardous substance but would still be a hazardous material.

If a shipper puts a toluene solution (70% toluene, 30% water) in a cargo tank, and the solution weighs 24,000 lb, the RQ to be applied is 1000 lb. Based on the table in Section 171.8, the concentration must meet or exceed 2% by weight. In this case, the toluene is 16,800 lb; thus, there is an RQ of this toluene solution.

A hazardous substance is subject to the HMR by all modes of transportation, even if an "A" or "W" appears in Column 1 of the HMT. In such a situation, the "A" and "W" have no significance. The same rule holds true if the material is a hazardous waste. (See Sections 172.101(b)(2) and (5).)

For radioactive material, the RQ values are located in Table 2 of Appendix A. A radioactive material is a hazardous substance when the activity per package meets or exceeds the activity levels shown in the RQ table. Find "Americium-241" ($^{241}$Am) in Table 2 of the appendix. The RQ value is 0.00037 TBq (0.01 Ci).

Reportable Quantity Determinations for Hazardous Waste

RQ values are set for materials that are constituents in a waste stream (e.g., acetone, lead, and chromium), and the values are also set for the various waste streams and codes (e.g., F003, D008, and D006). The appropriate RQ for a hazardous waste depends on the amount of information available on the waste stream, including the constituents of the waste stream, their amount per package, and their respective concentrations.

If the constituent of a waste and its respective concentration are known within a specified range <u>and</u> the packaging size does not permit the constituent at its highest concentration to meet or exceed its RQ, this information may be used to determine the constituent is not a hazardous substance. If all or some of the waste's constituents or their respective concentrations are unknown, then the RQ will be based on the mass of the waste rather than the amount of the constituent(s) within the waste.

Consider the following scenarios:

<u>Scenario 1</u>: The shipper has a 55-gallon drum containing 400 lb of waste that meets the criteria for the characteristic of ignitability (D001 waste). The flammable liquid in the waste is isopropanol. Isopropanol is not listed in the RQ table; however, the RQ for unlisted hazardous waste with the characteristic of ignitability (waste code D001) is set at 100 lb. In this case, the shipper has an RQ because there is greater than 100 lb of a D001 waste.

<u>Scenario 2</u>: The shipper has spent halogenated solvents used in degreasing (F001 waste) that consist entirely of 1,1,1-Trichloroethane. The "default" RQ value for an F001 waste stream is 10 lb. The RQ value for 1,1,1-Trichloroethane as a F001 waste constituent is 1000 lb. Since the shipper knows the constituents and the percentage of the waste, the RQ value is the one associated with 1,1,1-Trichloroethane.

<u>Scenario 3</u>: The shipper has an F003 waste consisting of an unknown percentage of acetone and water. The RQ for F003 waste is 100 lb, and the RQ for acetone in F003 waste is 5000 lb. Since the concentration of acetone is not known, the shipper has an RQ when there is 100 lb or more of F003 waste in a package.

<u>Scenario 4</u>: The shipper has a 55-gallon drum containing 720 lb of soil contaminated with 10 ppm lead, which meets the criteria for hazardous waste with the characteristic of toxicity (D008 waste). The RQ for lead as a D008 waste is 10 lb. At 10 ppm, the amount of lead present in the soil is less than 1 lb. Therefore, there is not an RQ amount present.

## 2.8 MARINE POLLUTANTS

Marine pollutants are defined in Section 171.8. A marine pollutant is a material that is listed in Appendix B of the HMT. When it is in a mixture or solution, it must be in specified concentrations. Appendix B designates the marine pollutants that are considered to be severe marine pollutants. A severe marine pollutant is identified in Appendix B by the entry "PP" in the first column. Two key points to remember on marine pollutants:

- To be a severe marine pollutant, the material in the mixture or solution must be (a) identified by the "PP" designation in Appendix B and (b) in a package in a concentration that equals or exceeds 1% by weight of the mixture or solution.
- All other materials listed in Appendix B must in a mixture or solution in a concentration that equals or exceeds 10% by weight to be regulated as a marine pollutant.

LIST OF MARINE POLLUTANTS

| S.M.P. (1) | Marine Pollutant (2) |
|---|---|
| ..... | Bromine cyanide |
| ..... | Bromoacetone |
| ..... | Bromoallylene |
| ..... | Bromobenzene |
| ..... | ortho-Bromobenzyl cyanide |
| ..... | Bromocyane |
| ..... | Bromoform |
| PP..... | Bromophos-ethyl |
| ..... | 3-Bromopropene |
| ..... | Bromoxynil |
| ..... | Butanedione |
| ..... | 2-Butenal. stabilized |

*NOTE: Section 171.4 provides that marine pollutants packaged in nonbulk packaging are not regulated as marine pollutants when transported by highway, rail, or air. Marine pollutants in bulk packaging are regulated by all modes.*

## 2.9 REVIEW QUESTION SET 1

Answer the following questions using a current copy of 49 CFR 100–185.

1. Column 2 of the HMT contains which of the following:

   - Label requirements
   - Packaging information
   - **Proper shipping name**
   - Hazard class

2. Sulfuric acid (35% acid) is an authorized proper shipping name.

   **a. True 172.101(c)(6)**
   b. False

3. Which of the following is a proper shipping name?

   a. Uranyl nitrate **not listed**
   b. Marine pollutants, liquid **shown in italics; see Env. Haz. Sub.**
   **c. London purple**

4. The proper shipping name for cordite is "Powder, smokeless."

   **a. True shown in italics; see "Powder, smokeless"**
   b. False

5. Which of the following prefixes is optional in any shipping name?

   **a. "mono" as used in Iodine monochloride 172.101(c)(7)**
   b. "methyl" as used in Methylpentadienes
   c. "fluoro" as used in Fluorosulfonic acid
   d. None of the above

6. "Flammable liquid, n.o.s." would be a proper shipping name for gasoline.

   a. True
   **b. False Gasoline is specifically listed**

7. Ammonium chlorate may be offered for transportation by which of the following modes:

   a. Air
   b. Rail
   c. Motor carrier
   **d. None of the above; *Forbidden* is shown in Column 3**

8. The primary hazard class for "Acrylonitrile, stabilized" is –

   a. 8
   **b. 3 "3" is shown in Column 3; 6.1 is in Column 6 as the subsidiary hazard**
   c. 7
   d. 6.1

9. The identification number of acetaldehyde is:

   a. UN 9801
   b. UN 1074
   c. UN 1203
   **d. UN 1089**

10. The packing group required for acetone is:

   a. None
   b. Packing Group I
   **c. Packing Group II**
   d. Packing Group III

11. Acetone is not regulated for transportation by air because the symbol "A" is not indicated in Column 1 of the HMT.

   a. True
   **b. False 172.101(b)**

12. Refer to the HMT and indicate the mode or modes by which the following materials are regulated by placing an "X" in the appropriate column:

| MATERIAL | AIR | WATER | ALL MODES |
|---|---|---|---|
| Phosgene | | | X |
| Castor Beans | X | X | |
| Antimony Lactate | | | X |

13. All paints are hazardous materials regulated by 49 CFR.

   a. True
   **b. False; must meet the Class 3 criteria**

14. "Phenol, solid" may be shipped as hazard class 9.

   a. True
   **b. False "+" in Column 1 fixes the hazard class as 6.1**

15. A package containing 90 lb of allyl alcohol is regulated as a hazardous substance.

   a. True
   **b. False RQ = 100 lb**

16. A package containing 15 lb of mercury (contained in manufactured articles) is regulated only when offered or intended for transport by air.

   a. True
   **b. False "A" in Column 1; RQ = 1 lb**

17. Determine the RQ values for:

- Benzene — 10 lb
- Asbestos — 1 lb; ¢¢ friable forms only
- Lead — 10 lb; ¢ <100 micrometer pieces only
- Unlisted Hazardous Waste, D001 — 100 lb
- Cobalt- 60 ($^{60}Co$) — 0.37 TBq
- $^{241}Am$ — 0.00037 TBq

18. Using Section 173.2a, determine the appropriate hazard class for the following multihazard materials:

| Multihazard Materials | Hazard Class |
|---|---|
| Class 3, Packing Group II, and Class 8, Packing Group I liquid | 8 |
| Class 4.3, Packing Group I, and Class 6.1, Packing Group I (dermal) | 6.1 |
| Class 8, Packing Group III liquid, and Class 3, Packing Group I | 3 |
| Limited Quantity Class 7 and Class 8, Packing Group II | 8; see Sections 173.2a(c)(5) and 173.423 |
| Class 7 (not Liquid) and Class 3, Packing Group I | 7; see Section 173.2a(a) |
| Class 7 liquid and Class 9 | 7; see definition of Class 9 in Section 173.140; can't be Class 9 if mixed with another hazard |

19. Determine if the following are marine pollutants when offered by highway in bulk packaging: (percentages are by weight of the solution or mixture)

| | |
|---|---|
| Chlorine (100%) | Yes |
| Solid mercury compound (2%) | Yes, 171.4 |
| Cresote (wood tar) (6%) | No, Not Listed; see 171.8 Definitions |
| Lead compounds, soluble (21%) | Yes, SMP 1%; Listed, Non-SMP 10% |

20. Determine if the following waste solution is a hazardous substance: Waste (D001) acetone and benzene solution (fully characterized, 520 lb, with 76% acetone, 23% benzene, and the rest nonhazardous constituents)

The waste is fully characterized, so base the RQ on the individual constituents.
RQ of acetone = 5000 lb RQ of benzene = 10 lb
For benzene, you have: .23(520) = 115 lb.
So, the waste is a hazardous substance based on benzene.

## 2.10 HAZARDOUS WASTE

The EPA regulates and defines hazardous waste. When transported, the packaging is determined by the DOT regulations, and both the EPA and DOT have requirements for hazard communication. In 49 CFR 171.8, the DOT defines *hazardous waste* as any material that is subject to the EPA hazardous waste manifest requirements specified in 40 CFR 262.

The EPA considers a hazardous waste to be a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. Determining what is a hazardous waste is important because only waste that has certain attributes is regulated as hazardous waste under the regulations in 40 CFR.

Hazardous waste determinations are complex because waste is generated from many sources, ranging from industrial manufacturing process waste to batteries to fluorescent light bulbs. Hazardous waste comes in many forms, including liquids, solids, gases, and sludges. To cover this wide range, the EPA developed a system to identify specific substances known to be hazardous and provide objective criteria for including other materials. The regulations contain guidelines for determining what exactly is a waste (called a solid waste) and what is excluded from the hazardous waste regulations. In addition, the EPA promotes recycling and reducing the amount of waste entering the RCRA system by providing exemptions for some kinds of waste when they are recycled in certain ways.

### Hazard Waste Identification Process [261.3]

Proper hazardous waste identification is essential, and it can be very complex. One approach is for waste generators to answer the following questions about their waste material:

- Is the material a solid waste?
- Is the material excluded from the definitions of solid waste or hazardous waste?
- Is the waste a listed or characteristic hazardous waste?
- Is the waste delisted?

These questions are graphically shown in Figure 2-6.

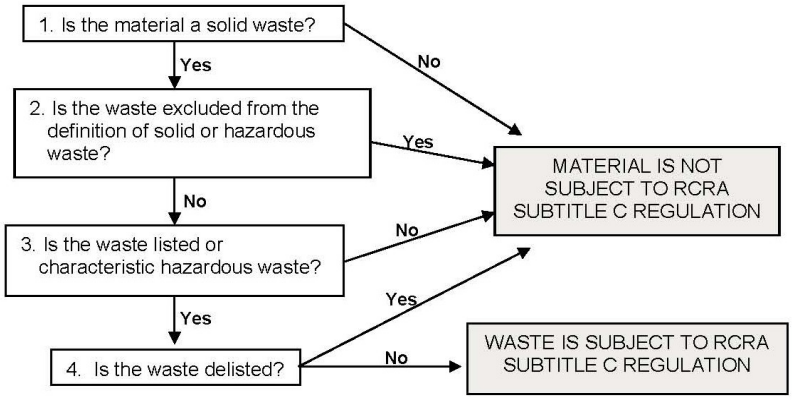



**Figure 2-6. Process for hazardous waste determination**

*Is the Material a Solid Waste? [261.2]*
The EPA uses the term *solid waste* to denote something that is a waste. In order for a material to be classified as a hazardous waste, it must first be a solid waste. Therefore, the first step in the identification process is to determine if the material is a solid waste.

The statutory definition of a solid waste is not based on the physical form of the material (solid, liquid, or gas) but rather that the material is a waste. The regulations define a solid waste to be any material that is discarded by being either abandoned, inherently waste-like, specific military munitions, or recycled. See Figure 2-7.

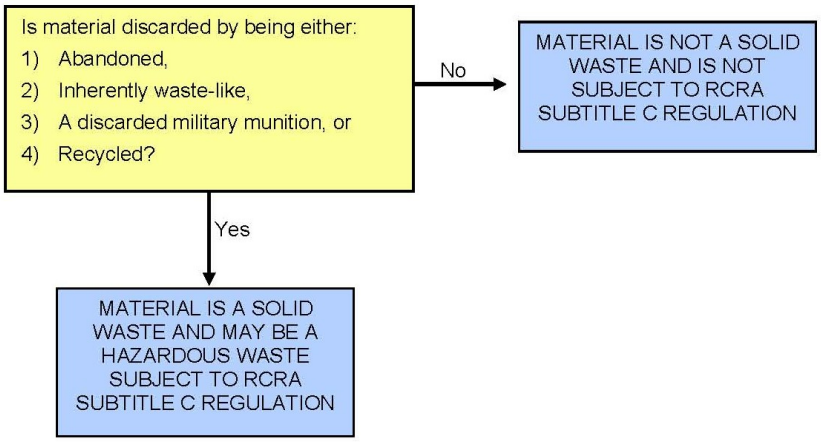



**Figure 2-7. Process for solid waste determination**

The term *abandoned* simply means thrown away. A material is abandoned if it is disposed of, burned, or incinerated. Inherently waste-like material is one that poses a threat to human health and the environment, and as such, these materials are always considered to be solid waste. An example is certain waste containing dioxin. Military munitions are considered solid waste when they are abandoned or treated prior to disposal, rendered nonrecyclable or nonusable through deterioration, or declared a waste by an authorized military official. Used munitions may also be solid waste if they are collected for storage, recycling, treatment, or disposal. A material is recycled if it is used or reused, reclaimed, or used in certain ways (e.g., burned for energy recovery). Figure 2-8 addresses recycled waste.

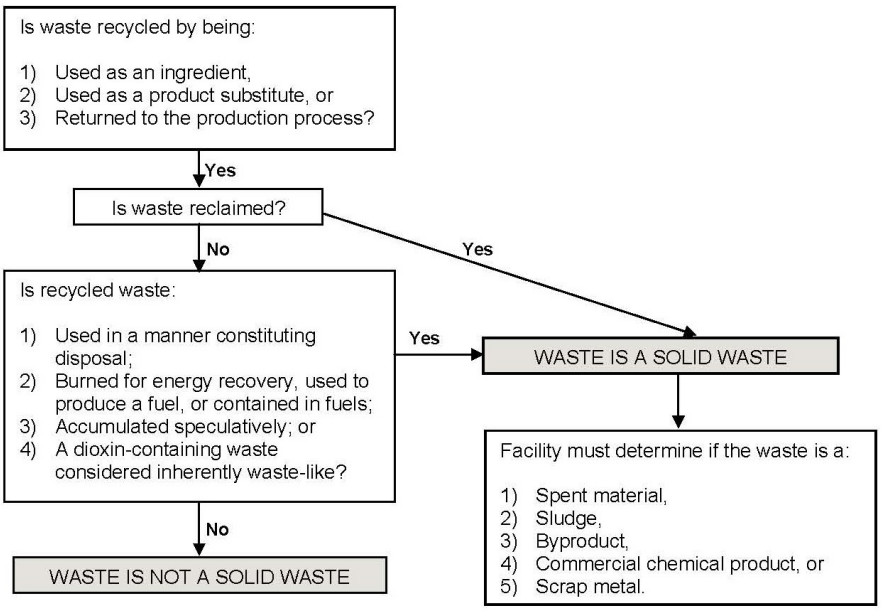



**Figure 2-8. Process for recycled waste determination**

*Is the Waste Excluded? [261.4]*
Not all solid waste qualifies as hazardous waste. Regulation of certain wastes may be impractical or otherwise undesirable. For example, household waste can contain dangerous chemicals such as solvents and pesticides, but subjecting households to RCRA waste management regulations would create a number of practical problems. Consequently, the EPA exempts or excludes certain waste from the hazardous waste definition and regulations. There are five exclusion categories:

- Exclusion from the definition of solid waste.
- Exclusion from the definition of hazardous waste.
- Exclusions for waste generated in raw material, product storage, or manufacturing units.
- Exclusions for laboratory samples and waste treatability studies.
- Exclusions for dredged material regulated under the Marine Protection Research and Sanctuaries Act or the Clean Water Act.

***NOTE: RCRA excludes radioactive material from the definition of solid waste. However, RCRA excludes only the radioactive components of the waste. If a radioactive waste is mixed with a hazardous waste, the resultant mixture is regulated as a mixed waste.***

The exclusion of certain samples is an important one for DOE and its contractors. Hazardous waste samples are essential to ensure accurate characterization and hazardous waste treatment. Samples sent to a laboratory for a waste determination are exempt from the RCRA regulations. (See Section 261.4(d).) The exemption applies to samples that are collected and shipped for the sole purpose of determining the hazardous waste characteristics or composition. These samples are still regulated by the DOT, and they must be appropriately classed and packaged based on the shipper's best knowledge of the material.

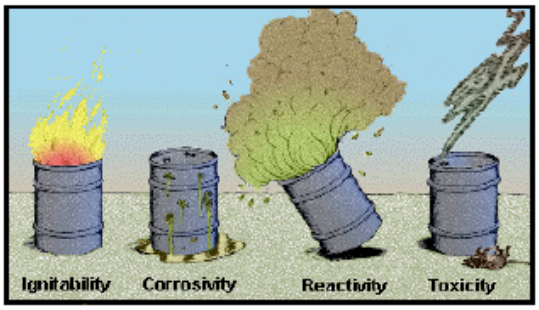
*Is the Waste a Listed Hazardous Waste? [261.30-33]*
Once the determination has been made that the waste is a solid waste and not excluded or exempt, the next step is to determine if the material is a listed hazardous waste in the RCRA regulations. Listed wastes are identified in 40 CFR 261, Subpart D. There are four lists:

- F List – Wastes from nonspecific common industrial and manufacturing processes
- K List – Wastes from specific industries
- P List – Wastes that are pure or commercial grade formulations of specific unused chemicals that are acutely toxic
- U List – Wastes that are pure or commercial grade formulations of specific unused chemicals

Each list includes anywhere from 30 to a few hundred hazardous wastes. Each listed waste is assigned an identification number known as a waste code (e.g., F001, K045).

*Characteristic Waste [261.20-24]*
Some wastes may not meet any of the criteria for the F, K, P, and U Lists, but they still pose threats to human health and the environment. Materials that have ignitability, corrosivity, reactivity, and toxicity characteristics are regulated as hazardous wastes.

- The ignitability characteristic identifies wastes that can readily catch fire and sustain combustion.
- The corrosivity characteristic identifies wastes that are acidic or alkaline (basic) and can readily corrode or dissolve flesh, metal, or other materials.



- The reactivity characteristic identifies wastes that readily explode or undergo violent reactions.
- The toxicity characteristic identifies wastes that are likely to leach dangerous concentrations of toxic chemicals into groundwater. This is determined by a procedure known as the Toxicity Characteristic Leaching Procedure.

*RCRA Requirements for Waste Generators*
The regulations applicable to generators of hazardous waste are contained in 40 CFR 261–262. Usually, waste generators are also the ones responsible for offering the waste for transport for disposal. A DOE contractor's waste management program can comply with the majority of the requirements, but there must be an interface with the transportation personnel. This interface usually includes marking and labeling the hazardous waste package and completing the shipping documentation.

The EPA defers the packaging requirements for hazardous waste to the DOT. (See Section 262.30.) Therefore, it is important for shippers to understand the various waste codes and characteristics so that they can compare these with the DOT hazard classes. For example, an EPA ignitable waste might meet the criteria for DOT Class 3, Packing Group II.

The EPA also requires that certain information be marked on hazardous waste containers. When these containers are transported, they must be marked and labeled in accordance with the DOT requirements in addition to the EPA requirements.

The EPA requires the use of a very specific shipping document called the Uniform Hazardous Waste Manifest (Form 8700-22). The manifest is a part of the EPA's cradle-to-grave waste tracking. The manifest contains many requirements unique to the EPA; however, it interfaces with the DOT by requiring that the document show a DOT shipping description.

Specific instructions for completing the manifest are found in 40 CFR 262. Additional information about the manifesting system is available from the EPA at http://www.epa.gov/epaoswer/hazwaste/gener/manifest/registry/index.htm.

The previous discussion was a brief overview and summary of some of the requirements, and it was not a complete discussion. It does, however, lay a foundation for discussing the packaging and transportation requirements for hazardous waste. Because of the complexity of the hazardous waste regulations, a thorough understanding of the RCRA requirements is required.

*Universal Waste*
EPA promulgated the universal waste program in 1995, and requirements for handling these wastes are found in 40 CFR Part 273. The universal waste program promotes collection and recycling of certain widely generated hazardous waste, designated as universal waste. Universal waste currently includes hazardous wastes that are: batteries, pesticides, lamps (e.g. fluorescent, neon, mercury vapor, etc.), and mercury containing equipment. Guidance from EPA for the generation, handling, transporting and recycling/disposal of universal waste can be found at http://www.epa.gov/epaoswer/hazwaste/id/univwast/index.htm.

Shipments of universal waste that meet any of the defining criteria of a hazardous material in 49 CFR must be made in compliance with the applicable regulations for packaging and hazard communication for these materials.

***NOTE: In accordance with 40 CFR 273.52, universal wastes do not require a Uniform Hazardous Waste Manifest. Therefore, they may not be offered under the "hazardous waste" proper shipping name or a proper shipping name amended to include the word "waste."***

## 2.11 REVIEW QUESTION SET 2

1. Under the EPA regulations, a solid waste can have what physical characteristics?

   **Solid, liquid, gas, semisolid**

2. What section of the EPA regulations defines *solid waste*?

   **261.2**

3. What section of the EPA regulations defines *hazardous waste*?

   **261.3**

4. What section of the EPA regulations excludes radioactive material from being a solid waste?

   **261.4(c)(4)**

5. Under what conditions can a radioactive material be regulated as a hazardous waste?

   **When a radioactive material is mixed with a RCRA material**

6. Match the following waste lists and codes with the corresponding criteria:

| | |
|---|---|
| F-listed waste | hazardous waste from a specific source **(K)** |
| K-listed waste | discarded off-specific chemicals and spill residues **(U)** |
| P-listed waste | hazardous waste from nonspecific sources **(F)** |
| U-listed waste | discarded commercial chemicals that are acutely toxic **(P)** |
| D001 | characteristic of reactivity **(D003)** |
| D002 | characteristic of ignitability **(D001)** |
| D003 | characteristic of corrosivity **(D002)** |

7. Will all DOT Class 8 material also meet the criteria for EPA hazardous waste meeting the characteristic of corrosivity? Why or why not?

   **No. The EPA corrosivity is for liquids only; the DOT has liquids and solids. The testing criteria are different.**

8. A liquid with flash point of 150°F meets the DOT definition of a combustible liquid. Does the same material meet the EPA characteristic of an ignitable waste?

   **No. 261.21(a)(1)**

9. Characterize trichloroethylene as a waste under the following conditions and assign an EPA waste code.

| | |
|---|---|
| Used in a process as a degreasing solvent | F001 261.31 |
| Column bottoms or heavy ends from the combined production of trichloroethylene and perchloroethylene | K030 261.32 |
| Trichloroethylene as a spill residue | U228 261.33 |
| Trichloroethylene that meets the characteristic of toxicity and in concentrations >0.5 milligram (mg)/liter | D040 261.24 |

10. What section of 40 CFR 262 specifies the packaging requirements for a hazardous waste?

262.30

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# CHAPTER 3

# RADIOACTIVE MATERIAL TRANSPORT FUNDAMENTALS

OBJECTIVES

- IDENTIFY THE AGENCIES THAT REGULATE RADIOACTIVE MATERIAL PACKAGING AND TRANSPORTATION.
- UNDERSTAND HOW AS LOW AS REASONABLY ACHIEVEABLE (ALARA) PRINCIPLES ARE REFLECTED IN THE REGULATIONS.
- UNDERSTAND HOW TO DETERMINE AND USE EXEMPTION VALUES FOR RADIOACTIVE MATERIAL.
- UNDERSTAND HOW TO DETERMINE AND USE THE $A_1$ AND $A_2$ VALUES.
- UNDERSTAND HOW TO DETERMINE THE RQ VALUES FOR RADIOACTIVE MATERIAL.
- UNDERSTAND THE ICAO/IATA REQUIREMENTS FOR AIR SHIPMENTS OF RADIOACTIVE MATERIAL.

## 3.1 INTRODUCTION

Radioactive material has been transported domestically and internationally for over 60 years. The safety record for transportation of radioactive material has been excellent. It is estimated that over four million packages containing radioactive material are transported in commerce annually within the United States.

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 during transport. This safety record can be attributed to the proper packaging of radioactive material and the effectiveness of the transportation safety standards and regulations.

Radioactive material is used to generate electric power and for research, manufacturing, and industrial processes, and it is indispensable for medical diagnosis and therapy. Radioactive waste is routinely transported in commerce. Radioactive material is transported by all modes (highway, rail, air, and water).

The DOT periodically updates the transportation regulations to address changing industry practices and maintain consistency with changing international standards. These changes are also aimed at maintaining and upgrading the existing excellent safety record.

### Background on the Radioactive Material Transport Regulations

The hazardous materials transportation safety program originated with the Transportation of Explosives and Other Dangerous Articles Act in 1908. The Interstate Commerce Commission was given responsibility for developing regulations to ensure the safe transportation of these materials in interstate commerce.

Transportation of radioactive material has been regulated since the 1930s. The earliest domestic standards were established by the USPS when radium sources were commonly shipped by mail. These early regulations addressed allowable dose rates, contamination levels, and separation and segregation distances to protect transportation workers and also to protect undeveloped film.

A more comprehensive set of regulations was promulgated in 1948 by the Interstate Commerce Commission, and radioactive material was regulated as a poison. In the early 1950s, the Interstate Commerce Commission 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 IAEA adopted radioactive material transportation regulations (standards) based largely on those of the Interstate Commerce Commission. These IAEA regulations became the first international radioactive material regulations. The IAEA recommended that member states and international transport organizations adopt the IAEA regulations as the basis or standard for their own domestic national requirements.

Later, in 1967, responsibility for domestic transportation safety was transferred from the Interstate Commerce Commission to the newly created DOT. In 1967, IAEA Safety Series No. 6 was substantially revised. This revision included a new category of material—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 served as the basis for a major revision of the HMR in 1968 related to radioactive material and, concurrently, a major revision of 10 CFR 71 by the NRC. These 1968 amendments brought the DOT and NRC regulations into essential conformity with the international standards.

In 1973, the IAEA completely revised Safety Series No. 6. The changes included a new system, $A_1/A_2$, for classifying radionuclides, which replaced the former transport group system. The special characteristics of large sources were now routinely considered 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 and the determination of when each country must approve the package design for an international shipment.

In 1983, the DOT and NRC both adopted regulations that were in essential conformity with the 1973 edition of the IAEA requirements in Safety Series No. 6. However, certain relatively minor exceptions and differences remained between the DOT and NRC regulations and the IAEA standards.

Two years after the DOT revised the HMR to conform to the IAEA 1973 standards, the IAEA again issued a comprehensive revision to Safety Series No. 6 in 1985. This edition was reprinted in 1990 with minor revisions.

In 1996, the IAEA revised the contents of Safety Series No. 6 again and renamed it ST-1. The explanatory/guidance companion document to ST-1 was issued by the IAEA as ST-2. The DOT's and NRC's current domestic regulations generally conform to ST-1. A revision to ST-1 is anticipated in 2009.

The current domestic regulations are published by three agencies (the DOT, NRC, and USPS). The international regulations are published by the IAEA, ICAO, and IMO.

## 3.2 DOMESTIC REGULATIONS

The DOT has regulatory responsibility for safety in the transport of all hazardous materials, including radioactive material. This includes shipments by all modes of transport in interstate, intrastate, or foreign commerce (rail, highway, air, and water) and by all means (truck, bus, automobile, vessel, airplane, railcar, etc.), except for postal shipments. Postal shipments are under the jurisdiction of the USPS.

Prior to 1967, the Interstate Commerce Commission had jurisdiction over both the safety and economic aspects of the transport of radioactive and other hazardous material by surface modes. Jurisdiction over safety was transferred to the DOT in April 1967. The modal administrations (Federal Highway Administration, Federal Railroad Administration, Federal Aviation Administration, and Coast Guard) each had separate regulations for the transport of hazardous material until 1974, when the Hazardous Materials Transportation Act was passed. At that time, a set of safety standards was developed which 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 of the possession, use, and transfer (including transport) of byproduct, source, and special nuclear material, i.e., *licensed material*. Due to this overlap in statutory authorities, the NRC and DOT signed a Memorandum of Understanding in 1979 with regard to regulating the transport of radioactive

material. The principal objective of the Memorandum of Understanding is to avoid conflicting and duplicative regulations and to clearly delineate the areas in which each agency establishes regulations.

In 10 CFR 71, the NRC promulgated requirements that must be met by licensees for the packaging used to deliver certain types of licensed material to a carrier for transport if it is fissile material or if the quantity exceeds Type A. The NRC also assists and advises the DOT in establishing both national and international safety standards and in reviewing and evaluating packaging designs. The NRC has adopted, by reference in 10 CFR 71.5, portions of the DOT regulations, enabling the NRC to inspect its licensees for compliance with the DOT regulations applicable to shippers/ licensees and to take enforcement actions on violations.

Over half of the states have entered into formal agreements with the NRC whereby the NRC transfers to those states its regulatory authority over licensed byproduct, source, and less-than-critical quantities of special nuclear material (fissile material). These *agreement states* have adopted uniform regulations pertaining to intrastate transportation of radioactive material. Generally, these regulations require the shipper to conform to the DOT requirements for packaging, labeling, placarding, and marking. Many of the states have formally adopted the DOT regulations by reference for both intrastate and interstate transportation.

***NOTE: The NRC and its agreement states regulate licensed shippers and receivers of radioactive material packages. Common and contract carriers are exempt from the requirement to obtain a license from the NRC or an NRC agreement state to the extent that they transport licensed radioactive material for someone else. (See 10 CFR 30.13, 40.12, and 70.12.) The DOT's authority applies to shippers and carriers, not to receivers.***

DOE contractors are generally not NRC licensees; thus, they are not directly regulated by the NRC. However, DOE contractors become subject to specific NRC requirements when using NRC-certified packaging and also through DOE directives. In addition, DOE contractors frequently ship to NRC licensees, and they may need to comply with some of the NRC requirements when shipping to a licensee's facility.

## 3.3 THE NRC'S TRANSPORT REGULATIONS

The NRC requirements that apply to transport of NRC-licensed radioactive material are located in 10 CFR 71. Several other transport-related requirements are also contained in 10 CFR 20 and 61. A brief overview of these requirements is provided in this section.

### 10 CFR 71

In accordance with 10 CFR 71.5, each NRC licensee who (a) transports licensed radioactive material outside the site of usage, as specified in the NRC license, or (b) transports the material on a public highway, or (c) delivers licensed material to a carrier for transport must comply with the applicable requirements of the DOT hazardous materials transport regulations. The NRC inspects the radioactive material shipping practices of its licensees and enforces compliance with the DOT regulations.
With the exception of DOT specification packages and packages approved by DOE, all packages with the following contents must be shipped in packaging certified by the NRC:

- Non-LSA/SCO Type B quantities.
- LSA/SCO Type B quantities for which the unshielded radiation level at 3 meters is greater than 10 millisievert (mSv)/hr (1 rem/hr).
- Fissile material which exceeds a fissile-excepted quantity.

The packaging approval standards for these materials are found in 10 CFR, Subparts D, E, and F. The user of an NRC-certified packaging must register with the NRC and make all shipments in compliance with the terms of the packaging approval.

### 10 CFR 20

Title 10 CFR Part 20.1906 requires that an NRC licensee who receives a radioactive package must monitor the package as follows:

- Except for packages containing gaseous or special form radioactive material, any package bearing any of the three categories of RADIOACTIVE labels must be monitored for external surface contamination.
- The external surface of any package containing greater than a Type A quantity (i.e., a Type B quantity) must be monitored on receipt for external radiation levels.
- 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.
- Instances of surface contamination and/or external radiation levels exceeding the applicable limits must be reported to the appropriate NRC regional office.

### 10 CFR 61

Title 10 CFR Part 61 contains regulations for siting and operating near-surface, low-level waste disposal sites, as well as the requirements for classification and the form of the materials 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 the 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 material or SCO) for shipment to a shallow land burial facility. Part 61 also contains specific requirements for the Radiological Waste Manifest information and format, which are more rigorous and detailed than the DOT requirements for shipping papers in 49 CFR 172.

Two important facts to remember about 10 CFR 61:

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

## 3.4 WHEN DOES THE DOT HAVE JURISDICTION?

The question of jurisdiction is important for DOE contractors to understand. Determination of the DOT's jurisdiction requires examining distinct operating environments. Determining jurisdiction can be tricky, and for a complex situation, it may require a formal interpretation from the regulator. For simple cases, the determination is a two-test process.

The first test involves the commercial nature of the transportation. The DOT HMR and the various modal safety regulations apply whenever transportation occurs in commerce. The DOT has interpreted and enforced *in commerce* to be when the transportation is not conducted wholly by a governmental entity. Therefore, transporting DOE material in a vehicle operated by a DOE employee (or a DOE contractor that is a state university employee) is not in commerce and not subject to the HMR or the various modal safety requirements.

Although offsite transportation activities performed by DOE contractors that are employees of a state university are not considered to be in commerce, DOE Order 460.1B requires that the contractor comply with the DOT regulations to the same extent as if the activity was in commerce.

If the shipment is determined to be in commerce, the second test must be examined. This test applies to the operating environment as it pertains to the public. Transporting a hazardous material

in commerce on a road where the public has unrestricted access is subject to the HMR. Likewise, transporting a hazardous material in a nongovernmental, contractor-driven vehicle on a road with public access restricted by gates/guards (i.e., on site) is not subject to the HMR.

The DOT FMCSR applies whenever a vehicle is operated on, along, or across a *public road*. Whether the road is public is determined by who owns or leases it, maintains it, and enforces the traffic laws. Thus, a nongovernmental contractor commercial motor vehicle containing hazardous material and operating on an unrestricted state, local, or city public highway is subject to the requirements of the HMR and the FMCSR.

When the DOT does not have jurisdiction, DOE directives and rules apply. The 10 CFR 830 safety basis requirements are applicable when the DOT does not have jurisdiction. DOE Order 460.1B includes provisions that require contractors which are governmental in nature (e.g., laboratories run by state universities) to comply with the regulations as if they were operating in commerce. In this case, the regulator is DOE, not DOT.

There are times when an offsite shipment is not regulated by the DOT, but it is subject to DOE regulations. For example, shipments made by DOE personnel (which do not meet the in commerce test) in government vehicles on interstate highways are not subject to the DOT HMR or the FMCSR. However, if the material on the vehicle meets the criteria for DOE nuclear Hazard Category 2 or 3 material, then the shipment is subject to the safety basis requirements in 10 CFR 830. The applicability of the DOT HMR to DOE contractors is summarized in Figure 3-1.

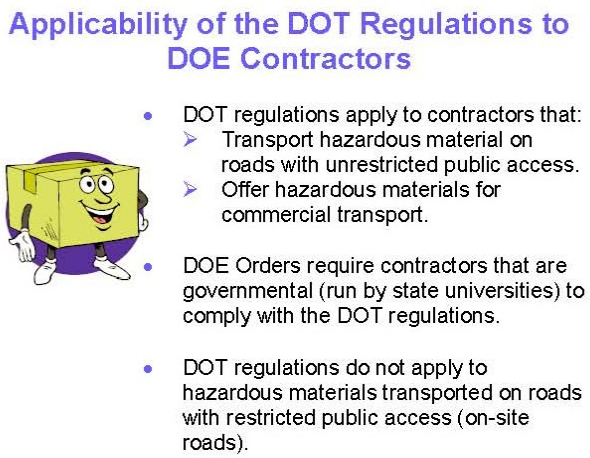



**Figure 3-1. Applicability of DOT regulations to DOE contractors**

DOE shippers need to understand the definitions of the pre-transportation functions covered by the HMR. (See the definitions in Section 171.8 and also Section 171.1 for applicability.) Anyone performing pre-transportation functions is subject to the applicable regulations, regardless that the functions are performed before transport occurs. Section 171.1 states that the HMR applies to the following:

- Persons who transport hazardous materials.
- Persons who cause hazardous materials to be transported in commerce.
- Persons who manufacture or maintain a package or a component of a package that is authorized for transporting hazardous materials in commerce.
- Persons performing pre-transportation functions, which include:
    - Determining the hazard class.
    - Selecting a hazardous materials packaging.
    - Filling a hazardous materials package.

- Securing a closure on a filled or partially filled hazardous materials package.
- Marking a package to indicate it contains a hazardous material.
- Labeling a package to indicate it contains a hazardous material.
- Preparing shipping papers.
- Providing and maintaining emergency response information.
- Reviewing a shipping paper to verify compliance with the HMR.

DOE contractors meet the definition of *person* under the regulations, and the functions listed above are typical of those performed by DOE contractors that package and transport hazardous materials in support of DOE's missions.

## 3.5 INTERNATIONAL REGULATIONS

There are a number of international bodies and organizations which deal with transportation of radioactive material. The majority of these international bodies are sanctioned by or affiliated with the 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 establishing the radioactive material regulations that have served as the basis for all other international regulations and requirements.

The ICAO is active in regulating the transport by air of dangerous goods, including radioactive material. The ICAO requirements have been adopted by nearly all countries. The IATA, a body of member air carriers, also publishes regulations for air transport of restricted articles, including radioactive material. Although the IATA is not recognized in the DOT regulations, the ICAO requirements are essentially restated in the IATA regulations.

For transport by ocean vessel, the IMO issues safety regulations for all types of hazardous materials, including radioactive material. The IMO regulations are published in the IMDG Code and reflect the UN's recommendations for all hazardous materials, which include the IAEA standards for radioactive material.

The IAEA, ICAO, and IMO regulations have been incorporated by reference in 49 CFR, thereby making their provisions enforceable by the DOT. See Section 171.7 and also Sections 171.22, 171.23, 171.24, and 171.25 in 49 CFR and USG 01 in the IATA regulations.

## 3.6 IMPORTANT RADIOACTIVE MATERIAL DEFINITIONS

Definitions important to understanding the regulations for radioactive material packaging and transportation are found in Section 173.403. Shippers need to understand the definitions for the following terms:

- $A_1$ and $A_2$
- Closed transport vehicle
- Consignment
- Contamination
- Criticality safety index (CSI)
- Exclusive use
- Exemption value
- Fissile material
- Highway route-controlled quantity
- Limited quantity of Class 7 material
- LSA (low-specific activity) material
- Low-toxicity alpha (α) emitters
- Multilateral approval
- Normal form Class 7 material
- Package
- Radioactive material
- Special form Class 7 material
- SCO (surface-contaminated object)
- Transport index (TI)
- Unilateral approval
- Uranium (U)—natural, depleted, enriched

## 3.7 PURPOSE OF THE RADIOACTIVE MATERIAL TRANSPORTATION REGULATIONS

The underlying philosophy of the regulations is that safety is ensured by the proper preparation of shipments by shippers, rather than relying on actions to be taken by carriers. The regulations provide that:

- Packages of radioactive material are treated in the same manner as any other hazardous material.
- Safety depends primarily on the package rather than on the operational controls.
- The shipper is responsible for ensuring safety during transport through proper characterization of the contents, proper packaging of those contents, and proper operational controls, including adequate hazard communication.

As with all aspects of handling radioactive material, the underlying principle is ALARA (i.e., to keep personnel exposures to levels that are as low as reasonably achievable). To achieve this during transport, consideration must be given to the transport system and how the freight is handled, as well as what stresses the freight is subjected to while in the transport system. The regulations require that packaging provide protection to workers, equipment, and the environment with minimal reliance on operational controls or human intervention. See Figure 3-2 below.

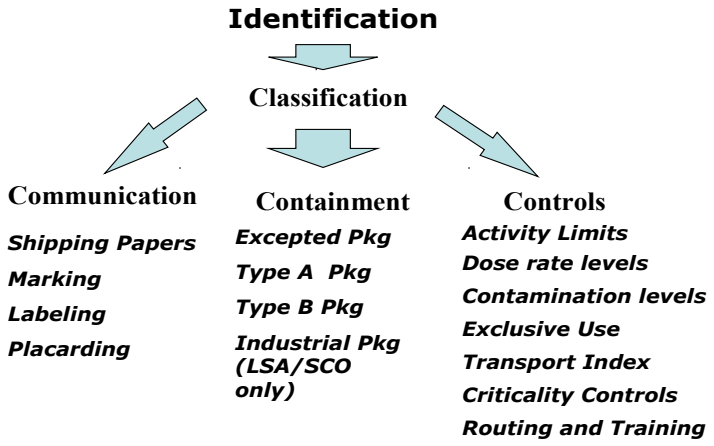



**Figure 3-2. Regulatory scheme for transporting radioactive material**

All radioactive material packages must meet regulatory standards that result in material containment, dose restriction, criticality prevention, and decay heat management. Packaging requirements are addressed by a graded approach commensurate with the physical properties and activity level associated with the radioactive material being shipped. Just as with other hazard classes, the DOT's system of identification, classification, containment, communication, and control applies to radioactive material shipments.

For example, when the regulations authorize exceptions in packaging (containment) or shipping paper, marking, or labeling requirements (communication), then the activity, dose rate, and contamination levels (controls) may be restricted to compensate. By balancing the packaging requirements with the activity/dose limits, the communication requirements, and the controls, the safe, economic shipment of radioactive materials is achieved.

## 3.8 DETERMINING RADIOACTIVE MATERIAL SHIPMENT REQUIREMENTS

All determinations concerning packaging and transporting radioactive material stem from the answers to the following questions:

1. *What nuclide(s) is/are being shipped?*

   Title 49 CFR Part 173.435 lists the $A_1$ and $A_2$ values for approximately 400 specific radionuclides. Title 49 CFR Part 173.433 provides a methodology for developing the values for unlisted, unknown, or mixtures of radionuclides. For unlisted nuclides, shippers may use the default values found in Section 173.433, Table 7, or obtain DOT approval for a derived value.

2. *How much activity is being shipped?*

   The packaging requirements are directly related to the total quantity of radioactivity in a package in terms of activity, e.g., TBq, Becquerel (Bq), Ci, millicurie (mCi), and microcurie (µCi). The basic International System of Units (SI) unit for a quantity of radioactive material is the Bq, and the customary unit is the Ci. For the radiation level, or dose rate, the basic SI unit is the Sievert (Sv)/hr, and the customary unit is rem/hr.

   ***NOTE: The IAEA and DOT have adopted the SI radiological units as the controlling units for transportation, and these must be shown on shipping papers and labels.***

3. *What form (solid, liquid, gas, or special form) is the material?*

   *Special form* is defined in the regulations in Section 173.403. For a material to be considered a special form, the shipper must have documentation showing that the tests listed in Section 173.469 were conducted and the criteria were met. Materials that are in special form are nondispersible. If the material is in special form, the quantity is compared to the $A_1$ value. Material in normal form is relatively dispersible, and it is solid, liquid, or gas. For material in normal form, the quantity is compared to the $A_2$ value.

   The table in Section 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 TBq and Ci.

   The $A_1$ and $A_2$ quantities for each radionuclide are 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 package than when the material is in normal form (i.e., not in special form).

### Special Form Radioactive Material ($A_1$)

Special form material is limited to a material which, if released from a package, presents 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 the inherent natural properties of the material, such as its being in a nondispersible solid form. Most often, however, it is an acquired characteristic resulting from being welded (encapsulated) into an extremely durable metal capsule.

Special form sources must have at least one external physical dimension which exceeds 5 millimeters (mm) (0.197 inches). 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 must be constructed in a manner that prevents the inadvertent loosening or opening of the capsule, either during transport or following an accident.

The testing requirements for determining whether a radioactive material qualifies as special form are found in 49 CFR 173.469, which describes the tests for high temperature, impact, percussion,

bending, and leakage. For import or export purposes, the shipper must furnish the carrier and the foreign consignee a Certificate of Competent Authority for the special form material.

For domestic shipments, the DOT does not require special form certificates when offering the material for transport as a special form. However, the shipper must have evidence that the source meets the special form standards, and the shipper must maintain that evidence on file for at least 1 year after shipment in accordance with Section 173.476(a).

A special form certificate issued by the DOT or by a foreign competent authority is acceptable evidence of a source being a 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 listed in 49 CFR 173.476.

***NOTE: An encapsulated sealed source need not be subjected to the impact and percussion tests of Sections 173.469(b)(1) and (2), provided it satisfies the Class 4 impact test prescribed in International Standards Organization (ISO) document ISO 2919, Sealed Radioactive Sources Classification. Also, it need not be subjected to the heat test listed in Section 173.469(b)(4) if it satisfies the Class 6 temperature test specified in ISO 2919.***

The activity limits for special form packages are stated in terms of $A_1$. The figures below illustrate typical special form radioactive material sources.

*Neutron Source* – Shows the empty inner and outer capsules with the plugs to be welded for sealing. This is typically an americium-beryllium (AmBe) source with 0.7 TBq (20 Ci) of $^{241}$Am.

*Industrial Radiography "Camera" and Source* – Shown with a connector cable called a "pigtail." The source is typically 4 TBq (100 Ci) of iridium-192.

*Normal Form Radioactive Material ($A_2$)* – As defined in Section 173.403, *normal form* radioactive material means a Class 7 material that does not qualify as a special form Class 7 material. These materials are solids, liquids, and gases. The normal (nonspecial) form package activity limits are stated in terms of $A_2$.

## 3.9 THE $A_1/A_2$ SPECTRUM OF PACKAGE ACTIVITY LIMITS

Once the nuclide(s), activity, and material form have been identified, the shipper needs to determine the proper shipping name and the packaging options. Aside from LSA material and SCO, radioactive material packaging choices relate directly to the $A_1/A_2$ values associated with each nuclide. The relationship between excepted packaging, Type A packaging, and Type B packaging to the $A_1/A_2$ value is shown on the shipping spectrum in Figure 3-3 below.

Figure 3-3 shows that the required packaging integrity increases with the activity level. For excepted quantity shipments (e.g., limited quantity, instruments, or articles) where the activity level is generally 1/1000 to 1/10,000 of what could be shipped in a Type A packaging, excepted packaging is allowed. The excepted packaging has to meet the general packaging requirements for radioactive material, which are provided in Section 173.410. Note that on the left side of the chart there is a threshold below which a radioactive material is not regulated. This threshold is found within the regulations in the definitions for radioactive material and contamination. The definition for *radioactive material* refers to established exemption levels on a per-nuclide basis. The definition for *contamination* establishes the surface contamination levels for nonradioactive contaminated items, below which the item is considered not to be regulated as Class 7 by the DOT.

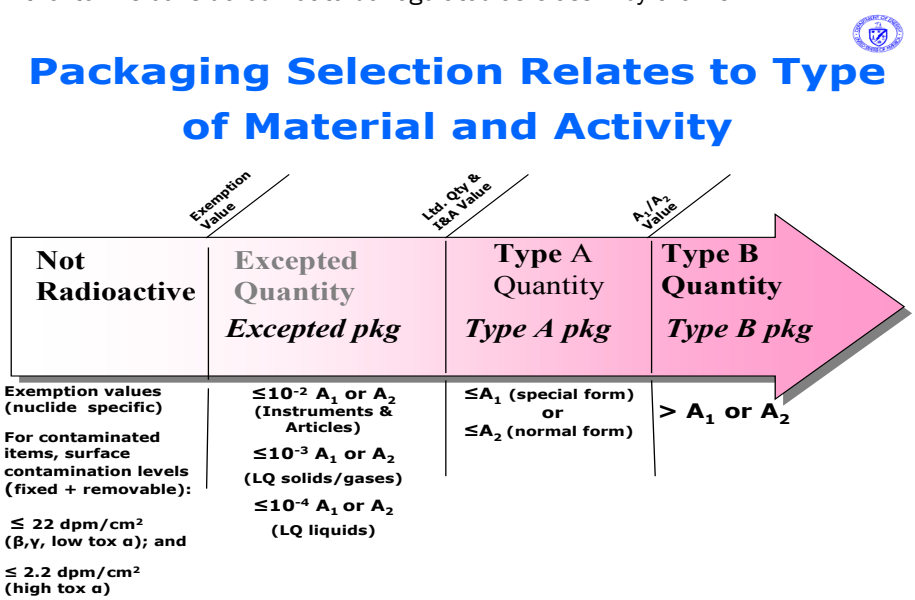



**Figure 3-3. Radioactive material shipping spectrum**

Type A quantities are authorized to be shipped in Type A packaging, which is designed to withstand the rigors of normal transport conditions. Generally, activity levels above the $A_1/A_2$ value must be packaged in Type B packaging, which is designed to withstand severe transportation accidents. As noted above, LSA material and SCO are treated differently, and their packaging requirements are discussed later in this manual.

The international regulations provide for a Type C package, which is for highway route-controlled quantity shipments by air. The domestic regulations have not adopted this type of package.

### When is a material regulated as Class 7?

The DOT regulates material as Class 7 (radioactive) material when the material exceeds specified activity levels. The DOT also regulates nonradioactive, contaminated items as Class 7 material when the contamination levels exceed specified values. Both these situations are described below. Review the definitions for *radioactive material* and *contamination* in Section 173.403.

## Radioactive Material

In 49 CFR 173.403, the DOT defines *radioactive material* to be ". . . any radioactive material containing radionuclides where both the activity concentration and the total activity in the consignment exceed the values in the table in 173.436 . . ." To be considered a radioactive material by the DOT, the material must exceed both the nuclide-specific exemption concentration limit and the consignment exemption activity limit. The underlying philosophy in deriving these exemption values is that the DOT should not regulate materials that are considered to be inherently safe, with inconsequential radiological concerns.

The exemption values were derived from the IAEA Safety Series No. 115, *Basic Safety Standards*, and they are based on an individual effective dose of 1 millirem (mrem)/year and a collective dose of 100 rem/year associated with a transportation activity. The activity concentration value is applied to the radioactive material within a package. The consignment activity exemption values were established for transporting small quantities of material that, when transported together, will have a total activity that is unlikely to result in any significant exposure.

The exemption values for individual nuclides are listed in the table in Section 173.436, a portion of which is extracted below in Figure 3-4. Several nuclides have a reference to footnote (b). The footnote states that the activity of the progeny (daughters) has been included for parent nuclides of decay chains, and the progeny activity is assumed to be in secular equilibrium with the parent. An explanation of secular equilibrium is provided later in this chapter.

| Symbol of radionuclide | Element and atomic number | Activity concentration for exempt material (Bq/g) | Activity concentration for exempt material (Ci/g) | Activity limit for exempt consignment (Bq) | Activity limit for exempt consignment (Ci) |
|---|---|---|---|---|---|
| Ac-225 | Actinium (89) | $1.0\times10^{1}$ | $2.7\times10^{-10}$ | $1.0\times10^{4}$ | $2.7\times10^{-7}$ |
| Ac-227 | | $1.0\times10^{-1}$ | $2.7\times10^{-12}$ | $1.0\times10^{3}$ | $2.7\times10^{-8}$ |
| Ac-228 | | $1.0\times10^{1}$ | $2.7\times10^{-10}$ | $1.0\times10^{6}$ | $2.7\times10^{-5}$ |
| Ag-105 | Silver (47) | $1.0\times10^{2}$ | $2.7\times10^{-9}$ | $1.0\times10^{6}$ | $2.7\times10^{-5}$ |
| Ag-108m (b) | | $1.0\times10^{1}$ | $2.7\times10^{-10}$ | $1.0\times10^{6}$ | $2.7\times10^{-5}$ |
| Ag-110m | | $1.0\times10^{1}$ | $2.7\times10^{-10}$ | $1.0\times10^{6}$ | $2.7\times10^{-5}$ |
| Ag-111 | | $1.0\times10^{3}$ | $2.7\times10^{-8}$ | $1.0\times10^{6}$ | $2.7\times10^{-5}$ |
| Al-26 | Aluminum (13) | $1.0\times10^{1}$ | $2.7\times10^{-10}$ | $1.0\times10^{5}$ | $2.7\times10^{-6}$ |
| Am-241 | Americium (95) | 1.0 | $2.7\times10^{-11}$ | $1.0\times10^{4}$ | $2.7\times10^{-7}$ |
| Am-242m (b) | | 1.0 | $2.7\times10^{-11}$ | $1.0\times10^{4}$ | $2.7\times10^{-7}$ |
| Am-243 (b) | | 1.0 | $2.7\times10^{-11}$ | $1.0\times10^{3}$ | $2.7\times10^{-8}$ |

**Figure 3-4. Exemption values for radionuclides (Section 173.436)**

For the listed decay chains, shippers need only compare the activity and activity concentration of the parent nuclide to the parent nuclide exemption value(s). Other mixtures (not decay chains) of nuclides must be evaluated using the equations in Sections 173.433(d)(6) and (7). The decay chains shown in footnote (b) include both long- and short-lived (≤10 days) daughters. This is different than footnote (a) to the $A_1/A_2$ table, which only references parent nuclides with short-lived daughters. The dosimetric model for the exemption values is different than the model used to derive the $A_1/A_2$ values.

Using Section 173.436, note that $^{241}$Am has a concentration exemption value of 1 Bq/gram (g) and a consignment activity exemption value of 10,000 Bq. Therefore, material containing $^{241}$Am would be regulated as a Class 7 material if shipped with more than 10,000 Bq in a single consignment <u>and</u> in a concentration greater than 1 Bq/g. Alternatively, a shipment with 74 Bq/g of $^{241}$Am and a total activity of 1 kilobecquerel (kBq) would not be regulated as Class 7.

When shipping mixtures where the nuclides are known but the associated individual activity is not known, the provisions in Section 173.433(f) should be followed, and the activity in the mixture should be assigned to the radionuclide with the most restrictive value. If the individual nuclides are not known, the shipper can use the values in Table 8, "General Exemption Values," and assign the

exemption values based on the type of energies emitted. Figure 3-5 below provides an example of exemption calculations for radioactive material.

**Exemption Calculations for Radioactive Material**

For a solution consisting of 80 milliliers (mL ) (112 g) of toluene, 6 kBq tritium ($^{3}H$), and 3 kBq carbon-14 ($^{14}C$), determine if the DOT regulates the material as radioactive.

First, determine the exemption concentration limits and consignment limits for $^{3}H$ and $^{14}C$.

From the table in Section 173.436:

$^{3}H$ (T): concentration limit: 1 E6 Bq/g consignment limit: 1 E9 Bq

$^{14}C$: concentration limit: 1 E4 Bq/g consignment limit: 1 E7 Bq

We have:

$^{3}H$ concentration: 6000 Bq/112 g = 53.6 Bq/g $^{14}C$ concentration: 3000 Bq/112 g = 26.8 Bq/g

Total activity concentration: 9000 Bq/112 g = 80.4 Bq/g

The fraction of activity concentration of $^{3}H$ is: 53.6/80.4 = .66
The fraction of activity concentration of $^{14}C$ is: 26.8/80.4 = .33

Using the equation from Section 173.433(d)(6), we determine the exempt activity concentration for the mixture to be:

$$\frac{1}{\Sigma\,[(\text{fraction of activity concentration})/\text{nuclide exemption concentration}]}$$

1/[(0.66/1 E6 Bq/g) + (0.33/1 E4 Bq/g)] = 1/(6.6 E-7 + 3.3 E -5) = **2.97 E 4 Bq/g**

**Since we only have 80.4 Bq/g, we have not exceeded the concentration limit.**

Using the equation in Section 173.433(d)(7), we determine the exempt consignment activity for the mixture to be:

$$\frac{1}{\Sigma\,[(\text{activity of nuclide/total activity})/\text{nuclide exemption activity}]}$$

1/[(0.66/1 E9 Bq) + ( 0.33/1 E7 Bq)] = 1/(6.6 E-10 + 3.3 E -8) = **2.94 E 7 Bq**

**Since our consignment activity is 9000 Bq, we also have not exceeded the consignment limit.**

As an alternative, rather than calculating the exemption limits for the mixture, you could use the unity equation and verify that the result is less than 1. For example, for the concentration limit:

$\Sigma$ (Activity concentration/exemption concentration) $\leq$ 1

(53.6/1 E6) + (26.8/1 E4) = .0001 + .0027 = **.0028**

For the consignment limit:

$\Sigma$ (Consignment Activity/exemption consignment activity) $\leq$ 1

(6000 Bq/1 E9) + (3000 Bq/1 E7) = 6 E-6 + 3 E-4 = **3 E-4**

**Since both determinations were less than 1, we have not exceeded the exemption limits.**

Based on the determinations above, the DOT would not regulate the material as Class 7. However, the toluene is regulated as a Class 3 flammable liquid and must be shipped accordingly.

**Figure 3-5. Example of exemption calculations for radioactive material**

## Contaminated Objects and Equipment

The DOT regulates nonradioactive solid objects with surface contamination as Class 7 material when both the surface contamination levels are above those in the definition of contamination in Section 173.403, and the activity of such objects in a consignment exceeds the exempt consignment limit in 173.436. Currently, the regulations do not provide an exempt consignment value for surface-contaminated items, although DOT issued letters of interpretation in 2008 that indicate that items, with surface contamination above the levels stated in the contamination definition, should be regulated as Class 7 when the total activity in the consignment is above the exempt consignment levels in Section 173.436.

*Contamination* is defined as the presence of a radioactive substance on a surface that is in excess of specified activity per surface area. The activity limits are established for beta (β), gamma (γ), and α emitters. The α emitters are further distinguished as either low-toxicity α emitters, or "all other α emitters." The definition for a low-toxicity α emitter is found in the definitions in Section 173.403.

Therefore, by definition, contamination is surface activity in excess of 0.4 Bq/square centimeters ($cm^2$) (22 disintegrations per minute [dpm]/$cm^2$) for beta/gamma and low-toxicity α emitters and 0.04 Bq/$cm^2$ (2.2 dpm/$cm^2$) for all other α emitters. It should be noted that these values are for surface contamination on the object (<u>not</u> contamination measured on swipes) and that the limits are for total contamination (fixed plus removable).

Note that the DOT contamination levels are not the same as the contamination levels established by the NRC and DOE to *free release* or to *green-tag* an item. Therefore, it is possible to green-tag an item that is regulated by the DOT as a Class 7 SCO when offered for transport in commerce. See the DOE contamination limits from 10 CFR 835 in Figure 3-6 on the following page.

As an example, metal pallets contaminated with enriched U (a high-toxicity α emitter) are regulated as Class 7 when the total surface contamination exceeds 2.2 dpm/$cm^2$ (220 dpm/100 $cm^2$) and the total activity in the consignment exceeds the exempt consignment value in 173.436.

In the IATA regulations, see the definition for Class 7 material in Section 3.7.1 and the discussion of contaminated items in Section 3.7.1(d). In the IMDG Code, see Part 2;2.7.1.

SURFACE CONTAMINATION VALUES[1] IN DPM/100 CM[2]

| Radionuclide | Removable[2 4] | Total (Fixed + Removable)[2, 3] |
|---|---|---|
| U-nat, U-235, U-238, and associated decay products | [7] 1,000 | [7] 5,000 |
| Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129 | 20 | 500 |
| Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133 | 200 | 1,000 |
| Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above[5] | 1,000 | 5,000 |
| Tritium and tritiated compounds[6] | 10,000 | N/A |

[1] The values in this appendix, with the exception noted in footnote 5, apply to radioactive contamination deposited on, but not incorporated into the interior or matrix of, the contaminated item. Where surface contamination by both alpha-and beta-gamma-emitting nuclides exists, the limits established for alpha-and beta-gamma-emitting nuclides apply independently.

[2] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[3] The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm² is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the surface contamination value if: (1) From measurements of a representative number of sections it is determined that the average contamination level exceeds the applicable value; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm² area exceeds three times the applicable value.

[4] The amount of removable radioactive material per 100 cm² of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note—The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 cm² is determined, the activity per unit area shall be based on the actual area and the entire surface shall be wiped. It is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

[5] This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

[6] Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface contamination value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore, a "Total" value does not apply.

[7] (alpha)

**Figure 3-6. DOE contamination limits from 10 CFR 835**

### $A_1/A_2$ Values

The regulations use the $A_1$ and $A_2$ values as points of reference for quantity limits for each radionuclide. Each radionuclide is assigned an $A_1$ and an $A_2$ value. These two values (in TBq) are the maximum activity of a radionuclide that may be transported in a Type A package.

The $A_1$ value is the activity limit for a particular special form radionuclide in a Type A package. The $A_2$ value is the activity limit that can be transported in a Type A package if the material is not in special form (i.e., it is in normal form).

The $A_1$ and $A_2$ values are used in the regulations as a normalized measurement of the 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 $A_1$ or $A_2$ or different fractions of $A_1$ or $A_2$ include:

- Ensuring special routing of packages with large quantities.
- Determining the total activity in packages and conveyances.
- Designating the limits for packages excepted from most requirements.
- Designating the specific activity of a contaminated material and associated packaging.

The derivation of the $A_1$ and $A_2$ values in the IAEA regulations is based on a series of dosimetric models (i.e., the Q System).

The limiting value for $A_1$ results from the worst-case assumptions of external direct γ radiation levels from an unshielded source at a certain distance. Generally, the $A_1$ value for a radionuclide is the quantity of that radionuclide which will result in a dose rate of 0.1 Sv/hr (10 rem/hr) at a distance of 1 meter.

The $A_2$ value, however, is based on the applicability of the most conservative worst-case value for five different scenarios, which include the $A_1$ scenario plus external β radiation to skin, inhalation, ingestion, and external γ radiation from immersion in a gaseous cloud of material released from a breached package.

As a result of an arbitrary limitation established by the IAEA, no radionuclides have been assigned $A_1$ or $A_2$ values greater than 40 TBq (1080 Ci). However, based on their LSA and low toxicity, some radionuclides were assigned unlimited $A_1$ and $A_2$ values.

The $A_1/A_2$ values have a direct relationship to radiation protection principles. The values are established based on potential exposures. The values in the 1985 IAEA regulations were derived using a dosimetric model intended to limit an individual's exposure due to a damaged package to the allowed annual dose limit for a radiation worker (5 rem). This was considered acceptable as a once-in-a-lifetime exposure for members of the public inadvertently exposed near an accident scene involving a Type A package. This dosimetric model, called the Q System, was an improvement over an earlier system that divided nuclides into transport groups based on toxicity. The revised Q System that is the basis for the $A_1/A_2$ values in the current domestic regulations no longer links to the annual dose limit for radiation workers; however, the 5 rem reference dose has been retained.

By definition, $A_1$ values apply to a nondispersible material that is in a special form. The $A_2$ values are for material in dispersible form (i.e., solids, liquids, and gases). Each value represents the maximum amount of activity that is authorized in a Type A package. Use of the $A_1/A_2$ values provides for a consistent, dose-based reference. An $A_2$ amount of any one nuclide represents the same potential hazard as an $A_2$ amount of any other nuclide. Because the $A_1/A_2$ values provide a normalized measurement of radiological risk, multiples or fractions of the $A_1/A_2$ values are also used for designating the activity per package and the conveyance, special routing for large quantity shipments, activity limits for excepted packages, and specific activity limits for contaminated material.

### Determination of the $A_1/A_2$ Value for Nuclides, Decay Chains, and Mixtures

The $A_1/A_2$ values are listed in 49 CFR 173.435, a portion of which is extracted below in Figure 3-7. Similar lists are included in the international regulations. For an individual nuclide that is not listed, the default values in Section 173.433, Table 7, may be used, or the shipper can follow the process in Section 173.433(c) and submit a value for approval to the Competent Authority (DOT).

**§ 173.435 Table of $A_1$ and $A_2$ values for radionuclides.**

The table of $A_1$ and $A_2$ values for radionuclides is as follows:

| Symbol of radionuclide | Element and atomic number | $A_1$ (TBq) | $A_1$ (Ci)[b] | $A_2$ (TBq) | $A_2$ (Ci)[b] | Specific activity | |
|---|---|---|---|---|---|---|---|
| | | | | | | (TBq/g) | (Ci/g) |
| Ac-225 (a) | Actinium (89) | $8.0\times10^{-1}$ | $2.2\times10^{1}$ | $6.0\times10^{-3}$ | $1.6\times10^{-1}$ | $2.1\times10^{3}$ | $5.8\times10^{4}$ |
| Ac-227 (a) | | $9.0\times10^{-1}$ | $2.4\times10^{1}$ | $9.0\times10^{-5}$ | $2.4\times10^{-3}$ | 2.7 | $7.2\times10^{1}$ |
| Ac-228 | | $6.0\times10^{-1}$ | $1.6\times10^{1}$ | $5.0\times10^{-1}$ | $1.4\times10^{1}$ | $8.4\times10^{4}$ | $2.2\times10^{6}$ |
| Ag-105 | Silver (47) | 2.0 | $5.4\times10^{1}$ | 2.0 | $5.4\times10^{1}$ | $1.1\times10^{3}$ | $3.0\times10^{4}$ |
| Ag-108m (a) | | $7.0\times10^{-1}$ | $1.9\times10^{1}$ | $7.0\times10^{-1}$ | $1.9\times10^{1}$ | $9.7\times10^{-1}$ | $2.6\times10^{1}$ |
| Ag-110m (a) | | $4.0\times10^{-1}$ | $1.1\times10^{1}$ | $4.0\times10^{-1}$ | $1.1\times10^{1}$ | $1.8\times10^{2}$ | $4.7\times10^{3}$ |
| Ag-111 | | 2.0 | $5.4\times10^{1}$ | $6.0\times10^{-1}$ | $1.6\times10^{1}$ | $5.8\times10^{3}$ | $1.6\times10^{5}$ |
| Al-26 | Aluminum (13) | $1.0\times10^{-1}$ | 2.7 | $1.0\times10^{-1}$ | 2.7 | $7.0\times10^{-4}$ | $1.9\times10^{-2}$ |
| Am-241 | Americium (95) | $1.0\times10^{1}$ | $2.7\times10^{2}$ | $1.0\times10^{-3}$ | $2.7\times10^{-2}$ | $1.3\times10^{-1}$ | 3.4 |
| Am-242m (a) | | $1.0\times10^{1}$ | $2.7\times10^{2}$ | $1.0\times10^{-3}$ | $2.7\times10^{-2}$ | $3.6\times10^{-1}$ | $1.0\times10^{1}$ |
| Am-243 (a) | | 5.0 | $1.4\times10^{2}$ | $1.0\times10^{-3}$ | $2.7\times10^{-2}$ | $7.4\times10^{-3}$ | $2.0\times10^{-1}$ |

**Figure 3-7. Extract of Section 173.435**

A number of nuclides in the $A_1/A_2$ table are part of decay chains, and the table contains entries for both the parent nuclide and progeny. When there are short-lived daughters (less than 10 days), the $A_1/A_2$ values for the parent have taken the daughter activity into account. The 10-day threshold was originally based on an assumed maximum 50-day transit time. For these decay chains, the progeny activity has been assumed to be in secular equilibrium, and the entries are denoted by a reference

to footnote (a) in the table. For these decay chains, the activity of the parent nuclide is compared to the $A_1/A_2$ value of the parent. (See Section 173.433(c)(2).)

When longer-lived daughters are present or the daughter is longer lived than the parent, the decay chain is treated as a mixture. Also, if the material has been altered (processed material) to where the distribution of nuclides is not the same as naturally occurring, then it should be treated as a mixture. These caveats are important to keep in mind when considering some DOE uranium shipments.

As with all tables in the regulations, the footnotes to the table in Section 173.435 are very important. Take a moment to look at the footnotes to the $A_1/A_2$ table, which are extracted on the following page in Figure 3-8. Scan through the table in Section 173.435, and note the entries where the footnotes are referenced.

| Symbol of radionuclide | Element and atomic number | $A_1$ (TBq) | $A_1$ (Ci)[b] | $A_2$ (TBq) | $A_2$ (Ci)[b] | Specific activity | |
|---|---|---|---|---|---|---|---|
| | | | | | | (TBq/g) | (Ci/g) |
| Zr-93 | | Unlimited | Unlimited | Unlimited | Unlimited | $9.3\times10^{-5}$ | $2.5\times10^{-3}$ |
| Zr-95 (a) | | 2.0 | $5.4\times10^{1}$ | $8.0\times10^{-1}$ | $2.2\times10^{1}$ | $7.9\times10^{2}$ | $2.1\times10^{4}$ |
| Zr-97 (a) | | $4.0\times10^{-1}$ | $1.1\times10^{1}$ | $4.0\times10^{-1}$ | $1.1\times10^{1}$ | $7.1\times10^{4}$ | $1.9\times10^{6}$ |

[a] $A_1$ and/or $A_2$ values include contributions from daughter nuclides with half-lives less than 10 days.
[b] The values of $A_1$ and $A_2$ in curies (Ci) are approximate and for information only; the regulatory standard units are Terabecquerels (TBq), (see § 171.10).
[c] The quantity may be determined from a measurement of the rate of decay or a measurement of the radiation level at a prescribed distance from the source.
[d] These values apply only to compounds of uranium that take the chemical form of $UF_6$, $UO_2F_2$ and $UO_2(NO_3)_2$ in both normal and accident conditions of transport.
[e] These values apply only to compounds of uranium that take the chemical form of $UO_3$, $UF_4$, $UCl_4$ and hexavalent compounds in both normal and accident conditions of transport.
[f] These values apply to all compounds of uranium other than those specified in notes (d) and (e) of this table.
[g] These values apply to unirradiated uranium only.
[h] $A_1$ = 0.1 TBq (2.7 Ci) and $A_2$ = 0.001 TBq (0.027 Ci) for Cf-252 for domestic use.
[i] $A_2$ = 0.74 TBq (20 Ci) for Mo-99 for domestic use.

**Figure 3-8. Footnotes to the A1/A2 Table**

## Uranium and Thorium Decay Chains

The thorium (Th) decay chain is shown graphically in Figure 3-9. Note the half-life duration for the various decay products and the associated decay mode (α/β/γ). Table 3-1 on the following page provides the $^{238}U$ and $^{235}U$ decay series.

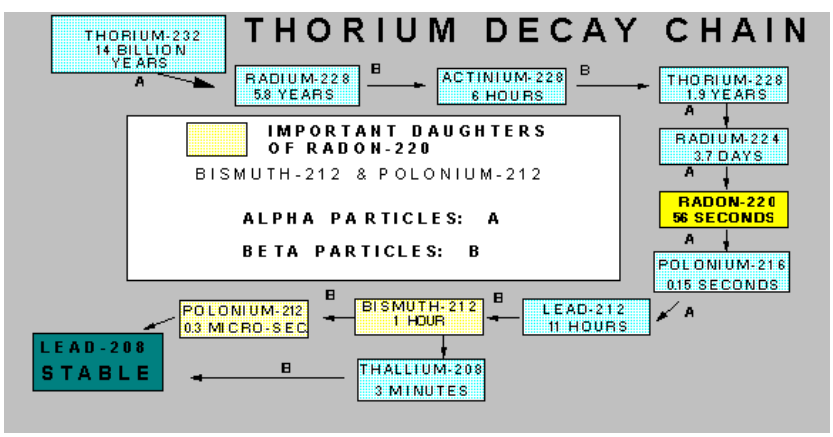



**Figure 3-9. Thorium decay chain**

**Table 3-1. Uranium-238 and Uranium-235 Decay Series**

| Uranium-238 Decay Series | | |
|---|---|---|
| **Nuclide** | **Half-Life** | **Radiation *** |
| U-238 | 4.468 x $10^9$ years | alpha |
| Th-234 | 24.1 days | beta |
| Pa-234m | 1.17 minutes | beta |
| U-234 | 244,500 years | alpha |
| Th-230 | 77,000 years | alpha |
| Ra-226 | 1,600 years | alpha |
| Rn-222 | 3.8235 days | alpha |
| Po-218 | 3.05 minutes | alpha |
| Pb-214 | 26.8 minutes | beta |
| Bi-214 | 19.9 minutes | beta |
| Po-214 | 63.7 microseconds | alpha |
| Pb-210 | 22.26 years | beta |
| Bi-210 | 5.013 days | beta |
| Po-210 | 138.378 days | alpha |
| Pb-206 | stable | --- |
| **Uranium-235 Decay Series** | | |
| **Nuclide** | **Half-Life** | **Radiation *** |
| U-235 | 703.8 x $10^6$ years | alpha |
| Th-231 | 25.52 hours | beta |
| Pa-231 | 32,760 years | alpha |
| Ac-227 | 21.773 years | beta |
| Th-227 | 18.718 days | alpha |
| Ra-223 | 11.434 days | alpha |
| Rn-219 | 3.96 seconds | alpha |
| Po-215 | 778 microseconds | alpha |
| Pb-211 | 36.1 minutes | beta |
| Bi-211 | 2.13 minutes | alpha |
| Tl-207 | 4.77 minutes | beta |
| Pb-207 | stable | --- |

Note: Only major decays are shown.

* In addition, all decays emit $\gamma$ radiation.

### Parent Nuclides with Short-Lived Progeny

The Q System takes decay chains into account. As stated before, a shipper usually just needs to take the value in the $A_1/A_2$ table assigned to the parent nuclide and make a comparison with the total activity. The Q System treats decay chains as a single nuclide if (a) the nuclides are in their naturally occurring proportions and (b) no daughter nuclide has a half-life either longer than 10 days or longer than the parent. Otherwise, the decay chain is treated as a mixture.

Short-lived daughters (less than 10 days) are assumed to be in secular equilibrium with the parent, and the assigned A value for the parent takes this into account. For the listed nuclides, when the A value assigned to the parent includes contributions by the short-lived daughter(s), there is a reference to footnote (a) in the table.

For example, strontium-90 ($^{90}Sr$) has a half-life of approximately 28 years, and it has a daughter, yttrium-90 ($^{90}Y$), with a half-life of approximately 64 hours. The $^{90}Y$ will come into secular equilibrium with the $^{90}Sr$ in approximately three to four weeks. The Q System assumes the short-lived daughter will reach secular equilibrium in transit, and the parent $A_1/A_2$ value shown in the $A_1/A_2$ table accounts for the daughter.

### Secular Equilibrium

Radioactive equilibrium for a decay chain occurs when each radionuclide decays at the same rate it is produced. At equilibrium, all radionuclides decay at the same rate. Understanding the equilibrium for a given decay series helps when estimating the amount of radiation that will be present at the various stages of decay.

When the half-life of the original radionuclide is much longer than the half-life of the decay product, the decay product generates radiation more quickly. Within about seven half-lives of the decay product, their activities are equal and the amount of radiation (activity) is doubled. Beyond this point, the decay product decays at the same rate it is produced—a state called *secular equilibrium*. This is shown in Figure 3-10.

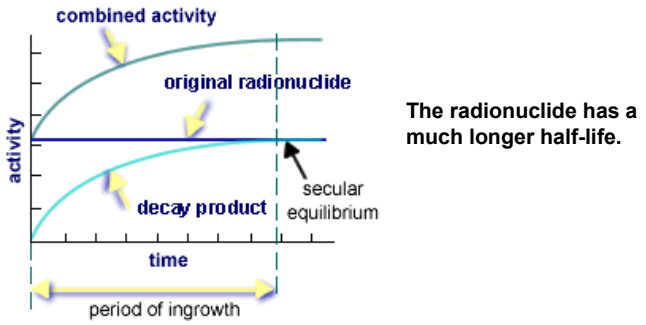



**Figure 3-10. Secular equilibrium**

If the half-life of the decay products is much longer than that of the original radionuclide, its activity builds up to a maximum and then declines. The original radionuclide eventually decays away, and no equilibrium occurs. This is shown in Figure 3-11 on the following page.

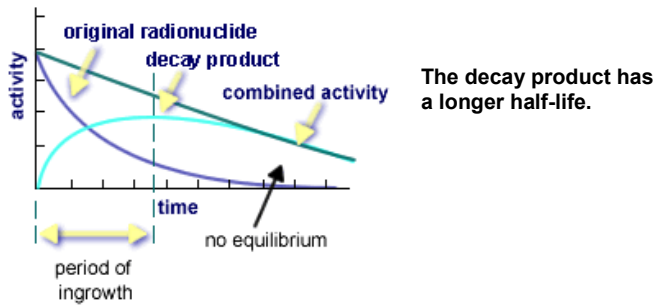



**Figure 3-11. Decay product has a longer half-life—no equilibrium**

### Determining the $A_1/A_2$ values for Mixtures

Section 173.433(d) of 49 CFR details two ways to determine if a Type A quantity of a mixture is present. The first method applies to both normal and special form material, and it provides a calculation to determine if the Type A limit has been exceeded. The second method applies to both normal and special form material and determines the $A_1$ or $A_2$ value for the mixture.

The first two equations in Sections 173.433(d)(1) and (2) are shown in Figure 3-12. These equations are sometimes referred to as unity equations, and they apply to mixtures either in normal or special form. The activity of each radionuclide is divided by its A value, and the resulting fractions are summed and compared to unity (1). If the sum is less than or equal to 1, then the Type A limit has not been exceeded. Subparagraph (d)(3) is used if there is a mixture of both special and normal form material.

$$\sum_j \frac{C(j)}{A_2(j)} \leq 1$$

Where:

C(j) is the activity of radionuclide j in normal form; and

$A_2(j)$ is the $A_2$ value for radionuclide j.

$$\sum_i \frac{B(i)}{A_1(i)} \leq 1$$

Where:

B(i) is the activity of radionuclide i in special form; and

$A_1(i)$ is the $A_1$ value for radionuclide i.

**Figure 3-12. Unity equations**

Alternatively, the above equation can be restated as:

$$\Sigma \text{ [activity of nuclide}/A_2 \text{ value for nuclide]} \leq 1$$

The equations shown in Sections 173.433(d)(4) and (5) relate the summed fraction of activity of each nuclide to the total activity in the mixture in either special or normal form, as appropriate. The equation produces a number in TBq that is the $A_2$ value for the mixture. This number can then be compared to the activity being shipped to determine if the Type A quantity has been exceeded or not. The equation in Section 173.433(d)(5) is shown below.

$$A_2 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_2(i)}}$$

Where:

f(i) is the fraction of activity for normal form radionuclide i in the mixture; and

$A_2(i)$ is the appropriate $A_2$ value for radionuclide i.

Alternatively, the above equation can be restated as:

$$A_2 \text{ for mixture} = \text{Total Activity} / \Sigma \text{ [activity of nuclide} / A_2 \text{ value for nuclide]}$$

Section 173.433(e) provides a method for determining the $A_1/A_2$ value if the nuclides are known, but an analysis has not been done to determine the activity associated with one or more of the nuclides. In such a case, the nuclides may be grouped according to the α or βγ activity, and the lowest $A_1/A_2$ value within each group would be applied. This method is particularly useful in the case of mixed fission products, which will usually also contain a proportion of transuranic nuclides. In this case, the grouping would be between α emitters and other emitters, using the most restrictive of the respective $A_2$ values for the individual nuclides within each of the two groups. This process accounts for the differing risk from the transuranic nuclides and the fission products.

In determining the total activity to be shown on shipping papers and labels and in determining the packaging type, a parent nuclide with daughters having less than 10-day half-lives is treated as a single nuclide, and the activity of the parent is applied. Although there may be more activity associated with this chain (because of the daughter activity), the $A_1/A_2$ values are based on the sum of the parent and daughter activity in secular equilibrium.

### Determining the $A_1/A_2$ Values When One or More Nuclide Activity is Unknown

When there is incomplete information about the nuclides present and/or their activity, Section 173.433(e) should be used. This section requires the activity in the mixture to be assigned to the most restrictive nuclide. This will result in a conservatively assigned $A_2$ value. Figure 3-13 provides two examples of $A_2$ calculations for mixtures.

In summary, when determining the $A_1$ or $A_2$ values:

- For single nuclides, use the values in the table in Section 173.435. [173.433(a)]
- For unlisted nuclides, use the "default" values in Table 7, or obtain another value from the DOT. [173.433(b)]
- For mixtures (including some decay chains), use the equations in Section 173.433(d)(1)–(5), as appropriate.
- For mixtures where some activities are not known, use Section 173.433(e) and apply the most restrictive value.

### What Nuclides Must Be Shown on Shipping Papers and Labels?

Sometimes, a large number of nuclides are being shipped. Section 173.433(g) specifies how to determine which nuclides must be shown. The DOT has determined that nuclides need to be listed based on their radiotoxicity and predominance in the mixture. This is accomplished using the equation shown in this section of the regulations, which determines those nuclides that represent 95% of the *weighted average* of activity. The weighted average incorporates the $A_1$ or $A_2$ value of the material. This results in nuclides with very low $A_2$ values (especially transuranics) always having to be listed.

$$\sum_{i=1}^{n} \frac{a_{(i)}}{A_{(i)}} \geq 0.95 \sum_{i=1}^{n+m} \frac{a_{(i)}}{A_{(i)}}$$

Where:

n + m represents all the radionuclides in the mixture;

m are the radionuclides that do not need to be considered;

$a_{(i)}$ is the activity of radionuclide i in the mixture; and

$A_{(i)}$ is the $A_1$ or $A_2$ value, as appropriate for radionuclide i.

***NOTE: Care should be taken in using this equation, since it "eliminates" nuclides with unlimited $A_2$ values. This can lead to confusing entries on shipping papers, and it can frustrate some fissile shipments. For example, consider a mixture of U enriched <20%, $^{60}Co$, $^{90}Sr$, and cesium-137 ($^{137}Cs$). The enriched U has an unlimited $A_2$ value. Using the equation for this mixture would result in a fissile shipment with no fissile nuclides being shown on the shipping papers and labels. While this is in compliance with the regulations, the inconsistency could look suspicious to an inspector.***

## Calculating and Using the $A_2$ Values for Mixtures

*Example 1*

Determine if the following solid palladium (Pd) mixture can be offered in a Type A package based on activity alone:

$^{103}$Pd 3 gigabecquerel (GBq)
$^{109}$Pd 0.4 GBq

Since our material is not in special form, we will use the $A_2$ values in the unity equation from Section 173.433(d)(2):

$$0.003 \text{ TBq}/40 \text{ TBq} + 0.0004 \text{ TBq}/0.5 \text{ TBq} =$$

$$0.0001 + 0.0008 = 0.0009$$

Since this value is less than 1 (unity), this mixture does not exceed the Type A limit.

*Example 2*

Determine the maximum amount of activity that can be offered in a Type A package for the following solid Pd mixture:

$^{103}$Pd 3 GBq
$^{109}$Pd 0.4 GBq

Using the equation in Section 173.433(d)(5): $A_2 = \dfrac{1}{\Sigma\,[(\text{Act/total activity})/A_2]}$

$$A_2 \text{ mixture} = 1/[(0.003 \text{ TBq}/0.0034 \text{ TBq})/40 \text{ TBq}] + [(0.0004 \text{ TBq}/0.0034 \text{ TBq})/0.5 \text{ TBq}]$$

$$= 1/(0.0221) + (0.2353) = 3.88 \text{ TBq}$$

Therefore, up to 3.88 TBq of this mixture may be offered in a Type A package. A Type B package would be required for activity levels exceeding this amount.

**Figure 3-13. Two examples of calculating and using the A2 values for mixtures**

## 3.10 DETERMINING RQ VALUES FOR RADIOACTIVE MATERIAL

The list of RQ values for radionuclides is located in Appendix A, Table 2, of the HMT. A portion of the table is shown below in Figure 3-14. The RQ values are shown in units of Ci and TBq. The footnotes to the table are very important, especially the ones designated ** and ***. In addition, when dealing with mixtures of radionuclides, it is important to read and understand paragraph 7, which is found immediately preceding Table 1 of Appendix A.

LIST OF HAZARDOUS SUBSTANCES AND REPORTABLE QUANTITIES

TABLE 2 TO APPENDIX A—RADIONUCLIDES

| (1)—Radionuclide | (2)—Atomic Number | (3)—Reportable Quantity (RQ) Ci (TBq) |
|---|---|---|
| Actinium-224 | 89 | 100 (3.7) |
| Actinium-225 | 89 | 1 (.037) |
| Actinium-226 | 89 | 10 (.37) |
| Actinium-227 | 89 | 0.001 (.000037) |
| Actinium-228 | 89 | 10 (.37) |
| Aluminum-26 | 13 | 10 (.37) |
| Americium-237 | 95 | 1000 (37) |
| Americium-238 | 95 | 100 (3.7) |
| Americium-239 | 95 | 100 (3.7) |
| Americium-240 | 95 | 10 (.37) |
| Americium-241 | 95 | 0.01 (.00037) |
| Americium-242 | 95 | 100 (3.7) |

TABLE 2 TO APPENDIX A—RADIONUCLIDES—Continued

| (1)—Radionuclide | (2)—Atomic Number | (3)—Reportable Quantity (RQ) Ci (TBq) |
|---|---|---|
| Americium-246m | 95 | 1000 (37) |
| Antimony-115 | 51 | 1000 (37) |
| Antimony-116 | 51 | 1000 (37) |
| Antimony-116m | 51 | 100 (3.7) |
| Antimony-117 | 51 | 1000 (37) |
| Antimony-118m | 51 | 10 (.37) |
| Antimony-119 | 51 | 1000 (37) |
| Antimony-120 (16 min) | 51 | 1000 (37) |
| Antimony-120 (5.76 day) | 51 | 10 (.37) |
| Antimony-122 | 51 | 10 (.37) |
| Antimony-124 | 51 | 10 (.37) |
| Antimony-124m | 51 | 1000 (37) |
| Antimony-125 | 51 | 10 (.37) |
| Antimony-126 | 51 | 10 (.37) |
| Antimony-126m | 51 | 1000 (37) |

**Figure 3-14. Extract of Appendix A, Table 2, of the HMT**

Paragraph 7 of Appendix A states that the RQ determination for a mixture depends on how much information is known about the individual nuclides and associated activities in the mixture. Shippers will utilize the unity equation and apply the most restrictive RQ or use a default value. It is important to understand each of the subparagraphs in this section of the regulations, which are provided on the following page.

> "7. For mixtures of radionuclides, the following requirements shall be used in determining if a package contains an RQ of a hazardous substance:
>
> (i) if the identity and quantity (in curies or terabecquerels) of each radionuclide in a mixture or solution is known, the ratio between the quantity per package (in curies or terabecquerels) and the RQ for the radionuclide must be determined for each radionuclide. A package contains an RQ of a hazardous substance when the sum of the ratios for the radionuclides in the mixture or solution is equal to or greater than one;
>
> (ii) if the identity of each radionuclide in a mixture or solution is known but the quantity per package (in curies or terabecquerels) of one or more of the radionuclides is unknown, an RQ of a hazardous substance is present in a package when the total quantity (in curies or terabecquerels) of the mixture or solution is equal to or greater than the lowest RQ of any individual radionuclide in the mixture or solution; and
>
> (iii) if the identity of one or more radionuclides in a mixture or solution is unknown (or if the identity of a radionuclide by itself is unknown), an RQ of a hazardous substance is present when the total quantity (in curies or terabecquerels) in a package is equal to or greater than either one curie or the lowest RQ of any known individual radionuclide in the mixture or solution, whichever is lower."

The U entries in the RQ Table and the footnotes to the RQ Table are shown below.

| | | |
|---|---|---|
| Uranium (Depleted) | 92 | *** |
| Uranium (Irradiated) | 92 | *** |
| Uranium (Natural) | 92 | ** |
| Uranium Enriched 20% or greater | 92 | *** |
| Uranium Enriched less than 20% | 92 | *** |
| Uranium-230 | 92 | 1 (.037) |
| Uranium-231 | 92 | 1000 (37) |
| Uranium-232 | 92 | 0.01 (.00037) |
| Uranium-233 | 92 | 0.1 (.0037) |
| Uranium-234 ** | 92 | 0.1 (.0037) |
| Uranium-235 ** | 92 | 0.1 (.0037) |
| Uranium-236 | 92 | 0.1 (.0037) |
| Uranium-237 | 92 | 100 (3.7) |
| Uranium-238 ** | 92 | 0.1 (.0037) |
| Uranium-239 | 92 | 1000 (37) |
| Uranium-240 | 92 | 1000 (37) |

**$** The RQs for all radionuclides apply to chemical compounds containing the radionuclides and elemental forms regardless of the diameter of pieces of solid material.
**†** The RQ of one curie applies to all radionuclides not otherwise listed. Whenever the RQs in TABLE 1, HAZARDOUS SUBSTANCES OTHER THAN RADIONUCLIDES, and this table conflict, the lowest RQ shall apply. For example, uranyl acetate and uranyl nitrate have RQs shown in TABLE 1 of 100 lb, equivalent to about one-tenth the RQ level for uranium-238 in this table.
** The method to determine the RQs for mixtures or solutions of radionuclides can be found in paragraph 7 of the note preceding TABLE 1 of this appendix. RQs for the following four common radionuclide mixtures are provided: radium-226 in secular equilibrium with its daughters (0.053 curie); natural uranium (0.1 curie); natural uranium in secular equilibrium with its daughters (0.052 curie); and natural thorium in secular equilibrium with its daughters (0.011 curie).
*** Indicates that the name was added by PHMSA because it appears in the list of radionuclides in 49 CFR 173.435. The reportable quantity (RQ), if not specifically listed elsewhere in this appendix, shall be determined in accordance with the procedures in paragraph 7 of this appendix.

Look at the entry for natural U in the RQ Table. Note that it references footnote **. This footnote addresses the fact that natural U is a mixture of $^{238}U$, $^{235}U$, and their daughter products. For natural U, natural Th, and radium-226 ($^{226}Ra$), the principles in paragraph 7 have been applied, and values for these mixtures are provided for use. Note that the shipper will need to determine if the U or Th is in secular equilibrium. This is fairly easy to determine from the analytical data, but if in doubt, a health physicist or some commercially available software can assist with in this determination.

Look at the entry for depleted U. Footnote *** is referenced, but it does not provide an RQ value. Since depleted U is primarily $^{238}U$ with a small amount of $^{235}U$ and associated daughter products, unless the analytical data indicates otherwise, the shipper will most likely use the value for $^{238}U$. For enriched U, the RQ value for $^{235}U$ will generally be applied unless the analytical data indicates otherwise.

## 3.11 TYPES OF RADIOACTIVE MATERIAL SHIPMENTS

Review the HMT for the proper shipping names beginning with "Radioactive material." All of the proper shipping names for Class 7 material and their associated UN ID numbers are shown below:

- UN 2909 "Radioactive material, excepted package-articles manufactured from natural uranium *or* depleted uranium *or* natural thorium"
- UN 2908 "Radioactive material, excepted package-empty packaging"
- UN 2911 "Radioactive material, excepted package-instruments *or* articles"
- UN 2910 "Radioactive material, excepted package-limited quantity of material"
- UN 2912 "Radioactive material, low specific activity (LSA-I) *non fissile or fissile excepted*"
- UN 3321 "Radioactive material, low specific activity (LSA-II) *non fissile or fissile excepted*"
- UN 3322 "Radioactive material, low specific activity (LSA-III) *non fissile or fissile excepted*"

- UN 2913 "Radioactive material, surface contaminated objects (SCO-I *or* SCO-II) *non fissile or fissile excepted*"
- UN 2919 "Radioactive material, transported under special arrangement, *non fissile or fissile excepted*"
- UN 3331 "Radioactive material, transported under special arrangement, fissile"
- UN 3327 "Radioactive material, Type A package, fissile *non-special form*"
- UN 2915 "Radioactive material, Type A package, fissile *non-special form, non fissile or fissile-excepted*"
- UN 3332 "Radioactive material, Type A package, special form *non fissile or fissile-excepted*"
- UN 3333 "Radioactive material, Type A package, special form, fissile"
- UN 3329 "Radioactive material, Type B(M) package, fissile"
- UN 2917 "Radioactive material, Type B(M) package, *non fissile or fissile-excepted*"
- UN 3328 "Radioactive material, Type B(U) package, fissile"
- UN 2916 "Radioactive material, Type B(U) package, *non fissile or fissile-excepted*"
- UN 2978 "Radioactive material, uranium hexafluoride, *non fissile or fissile-excepted*"
- UN 2977 "Radioactive material, uranium hexafluoride, fissile"

Notice that most of the proper shipping names include references to the type of packaging that is authorized and whether the material is fissile or in special form. Generally, the types of Class 7 shipments are excepted packaging, LSA/SCO, fissile, and Type A and Type B quantities in nonfissile packaging. Each type of shipment is discussed in detail later in this manual. In addition, uranium hexafluoride ($UF_6$) shipments are also discussed separately.

Using the HMT for Class 7 material is the same as for other hazard classes. Once the proper shipping name has been determined, the table provides references for the sections detailing the packaging requirements. The sections of the regulations detailing the hazard communication requirements for marking, labeling, placarding, and shipping papers also contain the specific requirements for Class 7 material.

## 3.12 RADIOACTIVE MATERIAL SHIPMENTS BY AIR AND WATER

For all hazardous material shipments offered for transport by air, the shippers must comply with the DOT regulations or, under the provisions in Section 171.22, 171.23, and 171.24, they are permitted to comply with the ICAO regulations. Most domestic air carriers require compliance with the ICAO regulations and the additional carrier requirements that are published annually by the air carriers in the IATA *Dangerous Goods Regulations*.

You should review the provisions in Section 171.23 and pay special attention to Section 171.23(b)(11), which contains the specific requirements for radioactive material. After reviewing this section, look at USG-10 in the IATA regulations. Note that many of the provisions in Section 171.23 are also reflected here.

Find the entries for radioactive material in the "List of Dangerous Goods" in Part 4 of the IATA regulations. Note that Special Provisions A130, A78, A139, A23, and A76 are referenced in Column M.

*Special Provision A130* – This provision is referenced for the entry "Radioactive material, excepted package-limited quantity of material." This special provision addresses limited-quantity radioactive materials with other hazardous properties. The requirements are similar to those found in 49 CFR 173.423.

*Special Provision A78* – This provision is listed for nonexcepted packaging proper shipping names, and it addresses the packaging and hazard communication requirements for Type A and Type B quantity radioactive material that has subsidiary hazards.

*Special Provision A139* – This provision is listed for proper shipping name entries that reference "non-fissile" or "fissile excepted."

*Special Provisions A23 and A76* – These provisions relate to shipments of $UF_6$. The specific requirements for the package and its marking, labeling, and shipping documentation for radioactive material are located in Part 10 of the IATA regulations and discussed in Chapter 9 of this manual.

*Special Provisions 290, 172, and 317* – The "Dangerous Goods List" in the IMDG Code references these three provisions for various Class 7 entries. Use of the IMDG Code is authorized in Sections 171.22, 171.23, and 171.25. For radioactive material, its conditions of use are detailed in Section 172.12(d).

- Special Provision 290 – This provision addresses limited quantity radioactive material with other hazardous properties.
- Special Provision 172 – This provision addresses the packaging and hazard communication requirements for Type A and Type B quantity radioactive materials that have subsidiary hazards.
- Special Provision 317 – This provision addresses fissile-excepted radioactive material shipments.

## 3.13 REVIEW QUESTION SET 3

1. Determine the $A_1$ and $A_2$ value for the following:

   $^{60}Co$ $A_1$: **0.4 TBq** $A_2$: **0.4 TBq**

   $^{241}Am$ $A_1$: **10 TBq** $A_2$: **0.001 TBq**

2. Determine the $A_2$ value for a solid mixture of 127 GBq of $^{137}Cs$ and 32 megabecquerel (MBq) of $^{90}Sr$.

   **$A_2$ = 0.605 TBq**

   **127 E-3 TBq/[(127 E-3/0.6) + (32 E-6/0.3)] =**

   **127 E-3/0.21 = 0.605 TBq**

3. The maximum activity that can be shipped in a Type A package is the **__$A_1$ or $A_2$___**for a nuclide or mixture of nuclides.

4. A highway route-controlled quantity is **$\geq$3000 X $A_1$ or $A_2$ or 1000 TBq, whichever is least.**

5. How is special form material different from material in normal form?

   **Special form is nondispersible, and the material must pass the tests in Section 173.469.**

6. Determine the RQ values for the following:

   $^{60}Co$ **0.37 TBq**

   $^{226}Ra$ (in secular equilibrium) **footnote to Table: 0.053 Ci = 0.002 TBq**

   $^{137}Cs$ **0.037 TBq**

   Depleted U **footnote to Table; use value for $^{238}U$ (0.0037 TBq) unless analytical data indicates otherwise**

7. The following materials are α emitters. Which are regulated by the DOT as low-toxicity α emitters? Circle the correct response(s).

   - Enriched U
   - **Natural Th ore**
   - **Radon-222 ($^{222}Rn$) (half-life ~ 4 days)**
   - $^{241}Am$ (half-life ~ 432 years)

8. Determine if the following are regulated as Class 7:

- One package with $^{90}Sr$ (25 Bq/g) in 5498 g of soil

  25 Bq/g (5498 g) = 137,450,000 Bq = 0.137 GBq

  Exempt concentration = 100 Bq/g
  Exempt activity = 10,000 Bq

  It does not exceed both exemption values, so it is not regulated as Class 7.

- Two packages offered as a single consignment

  - Pkg 1: $^{14}C$ 1 E8 Bq in 100 kg matrix
  - Pkg 2: $^{137}Cs$ 1 E3 Bq/3.2E12 Bq/g

  Using the sum of ratios equation:

  Activity Have/Exempt Activity = (1 E8 Bq/1 E7) + (1 E3/1 E4) >1; so exceeds limit

  Conc. Have/Exempt Conc. = (1000 Bq/g/1 E4) + (3.2 E12/10) >1; so exceeds limit

  Since both limits are exceeded, the consignment is regulated as Class 7.

- Contaminated equipment with the following associated survey data:

  Nuclides: U enriched, Pu, $^{99}Tc$, $^{241}Am$

  Removable (smear data): 3.43 dpm/100 $cm^2$ α
  6.77 – 8.25 dpm/100 $cm^2$ βγ

  Fixed contamination: ≤ 165 dpm/100 $cm^2$

  High toxicity α limit = 2.2 dpm/$cm^2$ (total contamination)

  Total contamination = fixed + removable; use highest value

  3.43(10) + 8.25(10) + 165 = 281.8 dpm/100 $cm^2$
  = 2.81 dpm/$cm^2$

  It is regulated as Class 7.

9. What section of the IATA provides the United States restriction for maximum allowable TI for a radioactive material package offered by passenger air?

   USG 10

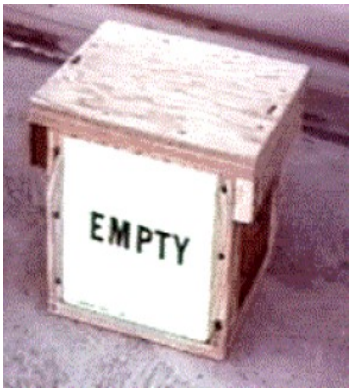
10. What is the maximum allowable TI for a radioactive material packaged offered by passenger air?

    3.0

# CHAPTER 4
# EXCEPTED PACKAGING SHIPMENTS

OBJECTIVES

- DETERMINE THE LIMITED QUANTITY ACTIVITY LIMITS FOR RADIOACTIVE MATERIAL.
- DETERMINE THE REQUIREMENTS FOR MAKING EXCEPTED PACKAGING SHIPMENTS.
- DETERMINE THE REQUIREMENTS FOR SHIPPING SMALL QUANTITY SHIPMENTS.
- DETERMINE HOW TO CLASS A LIMITED QUANTITY CLASS 7 MATERIAL THAT ALSO MEETS ANOTHER HAZARD CLASS DEFINTIION.



## 4.1 EXCEPTED QUANTITY RADIOACTIVE MATERIAL SHIPMENTS

When a small fraction of the $A_1/A_2$ activity is being shipped, it may be possible to have such shipments excepted from the full requirements for specification packaging, marking, labeling, and shipping paper requirements. Shipments that are eligible for these exceptions have the following proper shipping names associated with them:

- "Radioactive material, excepted package-limited quantity of material."
- "Radioactive material, excepted package-instruments *or* articles."
- "Radioactive material, excepted package-articles manufactured from natural *or* depleted uranium *or* natural thorium."
- "Radioactive material, excepted package-empty packaging."

The packaging sections referenced for these proper shipping names include Sections 173.421, 173.422, 173.424, 173.426, and 173.428. These sections, in addition to the activity or material restrictions, have restrictions on dose rates and contamination levels. These shipments may be shipped in packaging that meets the general design requirements in Section 173.410.

### Excepted Packaging

In addition to the general packaging requirements for all hazardous materials, excepted packaging must meet the general design requirements for radioactive material packaging in Section 173.410. Excepted packaging is authorized when smaller quantities or lower-hazard radioactive material is being shipped. Excepted packages are not required to be tested or designed to survive any transportation accidents, and it is assumed that all the contents could potentially be released under accident conditions. Therefore, the total activity and maximum allowable dose rates associated with these packages are significantly lower than those allowed for Type A and Type B packages.

### Limited Quantity Radioactive Material Shipments

In the HMT in 49 CFR, find the entry for "Radioactive material, excepted package-limited quantity of material." Note that the packaging sections in Column 8 refer to Sections 173.421 and 173.422. Section 173.421 restricts the allowable activity per package (as specified in Section 173.425), and it establishes the minimum packaging requirements, maximum surface dose rate, maximum removable surface contamination levels, and maximum allowable mass for fissile material.

Limited quantities are excepted from the marking and labeling requirements in Part 172 if the provision in Section 173.421(a)(4) is met <u>and</u> the package is marked with the UN ID number in accordance with Section 173.422(a). If the limited quantity is not also a hazardous substance or waste, then the shipping paper and certification requirements are also excepted.

The allowable activity limits for a limited quantity shipment are provided in Section 173.425, Table 4. This section is referenced in Section 173.421(a), and for instrument or article shipments, it is referenced in Section 173.424(b). Table 4 is shown in Figure 4-1 on the following page.

The activity limits for excepted packages are set based on an assumed total release of the contents during an accident; therefore, the activity is restricted based on the assumed releases associated with a Type A package. This affords the same level of protection, even though the packaging has a lower integrity.

TABLE 4—ACTIVITY LIMITS FOR LIMITED QUANTITIES, INSTRUMENTS, AND ARTICLES

| Nature of contents | Instruments and articles | | Limited quantity 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/L (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 | $10^{-3}$ $A_1$ | $10^{-2}$ $A_1$ | $10^{-3}$ $A_1$ |
| Normal 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 adsorbed on solid carriers.

**Figure 4-1. Table 4 - Activity Limits for Limited Quantities, Instruments, and Articles**

There are three main columns in this table: "Nature of contents," "Instruments and articles," and "Limited quantity package limits." The "Instrument and articles" column is further divided into two columns, and it is used when offering material under Section 173.424. For limited quantity shipments under Section 173.421, the third column ("Limited quantity package limits") is used to determine the maximum allowable activity per package. Note the footnotes to the table, especially Footnote 1, which refers back to the unity equation in Section 173.433(d) for mixtures of nuclides.

Under the applicable entry for solid, liquid, gas, or special form, Table 4 provides the activity limits ranging from $10^{-3}$ to $10^{-4}$ of the $A_1/A_2$ value. Exceptions to this are the values associated with tritium ($^3H$), which were determined separately based on its radiological properties. The values for tritiated water are provided only in the domestic regulations, and under the international regulations, the $10^{-4}$ $A_2$ value would be used. See Figure 4-2 on the following page for an example of a limited quantity determination.

Section 173.421(a)(2) specifies that the external dose rate at the package surface cannot exceed 0.5 mrem/hr. In addition, the removable contamination must not exceed the values in Section 173.443. The word *Radioactive* must be marked on either the outer packaging or on the inner packaging of a combination package. The outer package must be marked with the UN ID number.

### Limited Quantity Radioactive Material That is Also a Hazardous Substance or Waste

Limited quantities of Class 7 material that are present in an RQ amount and/or are mixed with a hazardous substance or a RCRA waste are not excepted from the shipping paper and certification requirements. Under Sections 173.421(a) and (b), these materials are subject to the shipping paper requirements. However, the shipping description under Section 172.203(d) and the certification in Section 172.204(c)(4) are not required. A typical shipping description involving a limited quantity Class 7 material mixed with RCRA waste and a hazardous substance is:

> 1 drum, RQ Waste UN 2910, Radioactive material, excepted quantity limited quantity of material, 7, (D001) 450 lb

**NOTE: Class 9 will not be a primary or subsidiary hazard when Class 9 material is mixed with materials meeting Class 1-7 criteria. See the definition of Class 9 in Section 173.140.**

**Limited Quantity Determination**

Determine if the following liquid Pd mixture can be offered in excepted packaging based on the activity alone:

| | |
|---|---|
| $^{103}$Pd | 3 GBq |
| $^{109}$Pd | 0.04 GBq |

Since the material is not in special form, we will use the $A_2$ values.

The $A_2$ value for $^{103}$Pd is 40 TBq, and for $^{109}$Pd, it is 0.5 TBq.

Therefore, at first glance, the activity of each nuclide is much less than the $A_2$ quantity, and it makes sense to see if the activity to be shipped is also below the limited quantity value.

For liquids, the limited quantity packaging limit from Table 4 is $10^{-4}$ $A_2$.

The limited quantity value for $^{103}$Pd is 0.004 TBq (4 GBq), and the limited quantity value for $^{109}$Pd is 0.00005 TBq (0.05 GBq).

Individually, each nuclide is below the limited quantity packaging limit; however, since this is a mixture, the unity equation must be used.

Using the unity equation from Section 173.433(d)(2):

Σ Have/Allowed less than or equal to 1:

Σ (3 GBq/4 GBq) + (0.04 GBq/0.05 GBq) =

0.75 + 0.8 = 1.55

Since this value is more than 1 (unity), this mixture exceeds the limited quantity packaging limit and should be shipped in a Type A package.

**Figure 4-2. Example of a limited quantity determination**

## Limited Quantity Radioactive Material Mixed with Material Meeting Another Hazard Class

Class 7 material mixed with other hazard class material is classed in accordance with Section 173.2a. This section stipulates that Class 7 material has the highest precedence, except when in limited quantities. When in limited quantities, Section 173.2a(c)(5) requires that the material be classed in accordance with Section 173.423.

Section 173.423 requires that the material be classed for the additional hazard, packaged in accordance with the requirements in Section 173.421(a)(1)–(5), and packaged and offered in accordance with the applicable requirements for the additional hazard. Including the phrase *Limited quantity radioactive material* after the basic description negates the need to comply with the requirements in Sections 172.203(d), 172.204(c)(4), and 173.422(a).

**Class 7 with Multiple Hazards**

- **Class per Section 173.2a**
  - Class 7 takes precedence except when limited quantity
  - When limited quantity, class for additional hazard and ship per Section 173.423
- **Small quantity section may be applicable (Section 173.4)**
  - Limited quantity Class 7 mixed with small amounts of other hazard classes
  - Must meet all conditions in Section 173.4
  - Specific packaging requirements

See also Section 3.10.3 and Special Provision 130 in the IATA regulations. In the IMDG Code, see Section 2.7.9 for the excepted quantity shipment requirements.

### Empty Radioactive Material Packages

The empty package provisions in Section 173.428 provide exceptions from certain requirements for a radioactive material package that has been emptied of its radioactive contents as far as practicable but which still contains residual radioactivity. This residual radioactivity limit, however, is not quantified or stated in terms of activity content. Instead, the limits are stated in terms of internal contamination with units of activity per $cm^2$. Such internal contamination is limited to 100 times the removable (nonfixed) contamination limits for the exterior package surfaces.

Empty packages are required to have the UN ID number on the outer packaging, and they must be labeled with the EMPTY label. Unless the package also meets the hazardous substance or waste criteria, empty package shipments are excepted from the shipping paper requirements.

*NOTE: The EMPTY label is not required under the IATA or the IMDG Code.*

### Limited Quantities of Radioactive Material in the Mail

The USPS regulations for mailing radioactive material are found in the *Domestic Mail Manual* and Publication 52, *Acceptance of Hazardous, Restricted, or Perishable Matter.* The *Domestic Mail Manual* prohibits any packages that either require a DOT RADIOACTIVE label or exceed the activity limits in Publication 52. Publication 52 allows for limited quantity, instruments, and articles, and articles containing natural U and Th shipments. A further restriction is placed on the shipments in that the activity per package is restricted to one-tenth of the allowable activity limits in 49 CFR.

### Limited Quantity Class 7 Material by Air and Water

Find the entry for "Radioactive material, excepted package-limited quantity of material" in the IATA "List of Dangerous Goods." Note the requirements in Special Provision A130 referenced in Column M. Section 10.5.9 of the IATA regulations contains the specific requirements for a limited quantity shipment. Table 10.5.A is similar to Table 4 in 49 CFR 173.425, with the notable difference in the entry for $^3H$. Section 10.5.9.2 lists the exceptions for limited quantity shipments, and Section 10.7.1.3.2 contains the marking requirements. Requirements for the Air Waybill are contained in Section 10.8.8.3.

Limited quantity Class 7 shipments are required to have the packages labeled with the RADIOACTIVE MATERIAL, EXCEPTED PACKAGE HANDLING label as referenced in Sections 7.2.4.6 and 10.7.4.4.3 of the IATA regulations.

Similarly, using the IMDG Code, Section 2.7.9, contains the provisions for excepted packaging shipments. Sections 5.2.1.5.1 through 5.2.1.5.3 contain the marking requirements. Shipping document requirements are contained in Section 5.4.1.4.1.1 and require the shipping document to show the UN ID number.

### Radioactive Material as a Small Quantity Shipment (49 CFR 173.4)

Title 49 CFR Part 173.4 allows a limited quantity of radioactive material that also meets another DOT hazard class definition to be offered as a small quantity shipment. In addition to meeting the requirements of Section 173.421(a)(1)–(5), the restrictive quantity limits, packaging, and communication requirements of Section 173.4 must be met.

### Environmental Samples

Frequently, environmental samples will meet the regulatory definition from a radioactive material standpoint. In addition, the samples may also meet another DOT hazard class definition.

When shipping environmental samples, the process is no different than shipping any other hazardous material. The shipper must classify the material and then select the appropriate packaging.

**Environmental Samples and Other Materials Without Full Characterization**

- **Likely shipping categories: Limited Quantity, Type A**
  - Assign $A_2$ based on Section 173.433(b) or (e)
- **If multiple hazards are involved (i.e., water samples preserved in acid):**
  - Small quantity (Section 173.4)
  - Multiple hazard limited quantity (Sections 173.2a, 173.423)
  - Limited quantity Class 7 (if mixed with only Class 9 material)
- **"Sample" provision [172.101(c)(11)]**
  - Not applicable to Class 7 material alone because the presence of Class 7 material should not be in question
  - For mixed hazard, use the defining criteria and Section 173.2a, as appropriate.

Environmental samples generally have low levels of radioactivity; therefore, they are frequently shipped as limited quantity shipments. If the samples contain acid preservatives that meet DOT Hazard Class 8 criteria, they are classed as described above for mixed hazard shipments.

Since the presence of radioactive material is easily determined by field instrumentation, radioactive environmental samples are generally not candidates to be offered under the "sample" provision in Section 172.101(c)(11).

## 4.2 REVIEW QUESTION SET 4

1. Determine the maximum activity allowed as a limited quantity for the following:

| | | |
|---|---|---|
| Iodine-131 as a liquid | $A_2$ = 0.7 TBq | LQ = $10^{-4}$ (0.7) = 0.07 GBq |
| $^{60}$Co as a solid metal | $A_2$ = 0.4 TBq | LQ = $10^{-3}$ (0.4) = 0.4 GBq |
| $^{241}$Am as a special form source | $A_1$ = 10 TBq | LQ = $10^{-3}$(10) = 10 GBq |

2. Can the following be offered as a limited quantity shipment?

| | |
|---|---|
| Nuclide/Activity: | $^{137}$Cs, as a solid oxide; 0.06 MBq |
| Package Surface Dose Rate: | 0.7 mrem/hr |
| Package Contamination level (removable): | less than 1800 dpm/100 cm$^2$ |

Regardless of activity, the dose rate is too high for limited quantity.

3. What package markings are required for:

- Limited quantity Class 7:
  - By highway: UN ID number; *Radioactive* either on inner or outer packaging, as appropriate, Section 173.421
  - By air: UN ID number; Names/Addresses; Gross Weight >50 kg; *Radioactive* on inner or outer packaging, as appropriate, IATA 10.7.1.3.2
- Empty package (by highway): UN ID number 173.428
- Small quantity shipment (by highway, Class 8, and limited quantity Class 7):

  173.4(a)(10) "This package conforms to 49 CFR 173.4"
  173.4(b), 173.421(a)(4) The word *Radioactive* on inner or outer packaging, as appropriate

4. What labels are required for:

- Limited quantity Class 7:
  - By highway: None
  - By air: RADIOACTIVE MATERIAL-EXCEPTED PACKAGE HANDLING label IATA 10.7.4.4.3
- Empty package: EMPTY
- Small quantity shipment: None

5. What are the internal and external contamination levels allowed for a Class 7 empty packaging shipment?

Internal: 100 X Table 9 Values External: Table 9 Values

## 4.3 REVIEW QUESTION SET 5

Based on the information provided for the materials listed below, indicate the applicable packaging category (excepted, Type A, or Type B), if there is an RQ, and what the proper shipping name should be.

1. By highway, 0.4 GBq Iodine-131 as a liquid chloride:

   Packaging Category: **Type A**
   RQ? **Yes**
   Proper Shipping Name: **Radioactive Material, Type A Package**

   **A2= 0.7 TBq LQ=$10^{-4}$(A2)=0.07 GBq RQ= 0.00037**

2. By highway, 5 GBq $^{241}$Am as an AmBe special form source:

   Packaging Category: **Excepted**
   RQ? **Yes**
   Proper Shipping Name: **Radioactive Material, Excepted Package–Limited Quantity of Material**
   Could this be offered in the United States mail? **No**

   **$A_1$ = 10 TBq LQ = 10 GBq USPS = 1 GBq RQ = 0.00037 TBq = 0.37 GBq**

3. By highway, liquid scintillation media, 6 kBq $^{3}$H, 3 kBq $^{14}$C, both in 80 mL (112 g) of toluene:

   Packaging Category: **Class 3, Packing Group II**
   RQ? **No**
   Proper Shipping Name: **Flammable Liquids, n.o.s.**

   **$^{3}$H $A_2$ = 40 RQ = 3.7 TBq Exempt Values: 1E6 Bq/g AND 1E9 Bq**
   **$^{14}$C $A_2$ = 3 RQ = 0.37 Exempt Values: 10,000 Bq/g AND 1E7 Bq Exempt**

4. By highway, neptunium-237 ($^{237}$Np), $^{230}$Th, and $^{90}$Sr as sealed source standards (not in special form), all in one package, with a total activity of 2.24 E-5 TBq:

   Packaging Category: **Type A**
   RQ? **No**
   Proper Shipping Name: **Radioactive Material, Type A Package**

   **$^{237}$Np $A_2$ = 0.002 RQ = 0.00037**
   **$^{230}$Th $A_2$ = 0.001 RQ = 0.00037**
   **$^{90}$Sr $A_2$ = 0.3 RQ = 0.0037 Assume all activity is with the Th: LQ = 0.001E-3 TBq**

5. By highway, Pu standard ($^{238}$Pu, 0.11 GBq), solid nitrate, meeting both Class 7 and 5.1:

   Packaging Category: **Type A**
   RQ? **No**
   Proper Shipping Name: **Radioactive Material, Type A Package**
   **$A_2$ = 0.001 LQ = 0.001 GBq RQ = 0.00037**

# CHAPTER 5

# LOW-SPECIFIC ACTIVITY (LSA) MATERIAL AND SURFACE-CONTAMINATED OBJECTS (SCOs)

## OBJECTIVES

- UNDERSTAND THE DIFFERENCES BETWEEN LSA MATERIAL AND SCO CATEGORIES.
- DETERMINE THE APPLICABLE PACKAGING REQUIREMENTS FOR LSA MATERIAL AND SCO.
- DETERMINE THE HAZARD COMMUNICATION AND CONTROLS REQUIRED FOR LSA AND SCO SHIPMENTS.

## 5.1 INTRODUCTION

The majority of waste material shipments from nuclear fuel cycle facilities and cleanup, remediation, and decontamination projects will be either LSA material or SCO shipments. The domestic regulations provide for significant regulatory relief for these materials in terms of packaging and hazard communication. Therefore, this is a frequently used shipping category by a majority of DOE sites.

## 5.2 DEFINITIONS OF LSA AND SCO

The definition of *low-specific activity* material is found in 49 CFR 173.403. There are three subcategories of LSA material, and each one has its own requirements for activity distribution, nuclides, and physical form. Each subcategory stands on its own merits.

The definition of *surface-contaminated object* is also provided in 49 CFR 173.403. For an SCO, the activity is distributed on the surface of a nonradioactive material rather than distributed within it as for LSA material.

The allowable activities associated with LSA material and SCO shipments were derived with the requirement that the unpackaged material would not produce radiation levels in excess of those allowed for Type A packages under accident conditions. Therefore, when LSA material and SCOs exceed the limit of 1 rem/hr at 3 meters, they must be placed in packaging tested for accident conditions.

*LSA-I Category* – This category is for material that has a very low specific activity, such as U and Th ores and their concentrates. The LSA-I category consists of:

- U and Th ores.
- Concentrates of U ore, Th ore, and other ores containing naturally occurring radionuclides that are intended to be processed for use of the nuclides.
- Solid, unirradiated natural U, depleted U, natural Th, or their liquid or solid compounds or mixtures.
- Nonfissile or fissile-excepted material with unlimited $A_2$.
- Nonfissile or fissile-excepted material with activity distributed throughout and an estimated average specific activity not exceeding 30 times the exemption concentration values.

*LSA-II Category* – This category was envisioned to include nuclear reactor process wastes, such as lower-activity resins and filter sludge. It can also include activated equipment. The activity does not have to be uniformly distributed, but it does need to be distributed throughout. The LSA-II category consists of:

- Tritiated water (0.8 TBq/liter).
- Solids with activity distributed throughout and estimated average specific activity not exceeding $10^{-4}$ $A_2$/g.
- Liquids with activity distributed throughout and estimated average specific activity not exceeding than $10^{-5}$ $A_2$/g.

*LSA-III Category* – This category is for higher-activity materials, such as solidified resins and cartridge filters. The LSA-III category consists of:

- Solids with activity distributed throughout the solid or group of solids or activity uniformly distributed in a solid, compact binding agent.

- Material with not more than 0.1 $A_2$ leached in 7 days.
- Material with not more than 2 x $10^{-3}$ $A_2$/g.

The leaching rate limit of 0.1 $A_2$ per week is based on a scenario where a solidified material in a drum is exposed to rain, and there is an assumed film of water within the package. If the package is then involved in a handling accident, some of the liquid may escape and be available to expose a person near the accident scene.

There are two categories of SCO, and SCO-II allows for higher contamination levels than SCO-I. It should be noted that the definition of *contamination* in Section 173.403 establishes the lower regulatory limits for surface contamination. Items with surface contamination levels below the levels stated in the definition are not regulated as radioactive material by the DOT. See Figure 5-1 for an overview of the SCO contamination limits.

| | SCO-I | | SCO-II | |
|---|---|---|---|---|
| | *β, γ, and low toxicity α* | *high toxicity α* | *β, γ, and low toxicity α* | *high toxicity α* |
| **Removable Contamination (accessible)** | **220 dpm/cm²** | **22 dpm/cm²** | **22,000 dpm/cm²** | **2,200 dpm/cm²** |
| **Fixed Contamination (accessible)** | **$2.2 \times 10^6$ dpm/cm²** | **$2.2 \times 10^5$ dpm/cm²** | **$4.4 \times 10^7$ dpm/cm²** | **$4.4 \times 10^6$ dpm/cm²** |
| **Fixed + Removable Contamination (inaccessible)** | **$2.2 \times 10^6$ dpm/cm²** | **$2.2 \times 10^5$ dpm/cm²** | **$4.4 \times 10^7$ dpm/cm²** | **$4.4 \times 10^6$ dpm/cm²** |

*Bq values are rounded up from .037*

**Figure 5-1. SCO-I and SCO-II maximum surface contamination levels**

Note that the SCO limits are denoted for both accessible and inaccessible surfaces. Examples of inaccessible surfaces include:

- Inner surfaces of pipes that have ends which can be securely closed.
- Inner surfaces of equipment that have been blanked off or closed.
- Gloveboxes with access ports blanked off.

The LSA and SCO limits were derived based on specific assumptions under accident scenarios. The LSA dosimetric model assumes an uptake of 10 mg of material by an individual after an accident. The $10^{-4}$ $A_2$/g limit for LSA-II solids gives the same level of safety as Type A quantities in Type A packaging.

The SCO models were based on surface-contaminated equipment from the fuel cycle with primarily fission product contaminates. Based on the allowable contamination for βγ emitters, an object with 10 $cm^2$ surface area could have fixed contamination up to 4 GBq and removable contamination up to 0.4 MBq. During an accident, it is assumed that:

- 20% of the SCO-I surface is scraped.
- 20% of the fixed contamination is released.
- All of the removable contamination is released.

Based on individual intake assumptions, the SCO limits for contamination afford the same level of safety as Type A quantities in Type A packaging.

## 5.3 INSIGHTS FROM NRC NUREG-1608

The NRC guidance document NUREG-1608/RAMREG-003, *Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Object*, was issued by both the NRC and the DOT in 1998. Understanding this document, along with the applicable regulations, is essential to making compliant LSA/SCO shipments. Some of the information in this document changed with issuance of the DOT rule (DOT docket number HM-230) and the companion NRC final rule in 2004; however, the majority of the document is still valid and helpful. This document is available on the internet at http://rampac.energy.gov/.

The NUREG provides information in a user-friendly format, and it addresses frequently asked questions about LSA material, SCO, and shipping requirements. The document also provides shippers with a clear indication of how the regulatory agencies view compliance with their regulations. While not having the full force of law, the document is very useful because it provides information as to what the regulatory agencies consider acceptable practices and methods to achieve compliance with the regulations. Shippers can take different approaches than what is presented in the guidance. However, if the guidance in the NUREG is followed, there is less chance that a regulator will take issue with a shipment. The following pages provide some highlights from the NUREG that are of particular importance to DOE.

### Characterizing an SCO [NUREG, 3.3, 3.3.1, 3.3.2, 3.4.5]

From the SCO definition, it is clear that the shipper must know what nuclide(s) are contaminating the item so that the appropriate limit can be applied. In addition, the shipper must know how much activity is distributed on the item's surface. The NUREG states that the level of precision needed for this information depends on whether or not the total activity in the package exceeds the $A_2$ quantity. Therefore, it is imperative that, at a minimum, the shipper must have enough information to determine the nuclide(s) and total activity. If the SCO item(s) in the package has an activity that does not exceed the $A_2$ value, then a more qualitative than quantitative evaluation may be made.

Packages with less than an $A_2$ quantity can be shipped as SCO-II without having detailed quantitative determinations of accessible fixed or total inaccessible contamination levels. In lieu of these determinations, the shipper must comply with all of the following:

- There must be less than an $A_2$ quantity present.
- The removable contamination levels on the accessible surfaces must be less than the SCO-II limit.
- The activity distribution on the object(s) is distributed throughout (not highly localized), and the total activity on the object, divided by its mass, must meet the LSA-II limits.
- The $\alpha$ emitter contribution within the package must be less than 0.025 of the $A_2$ quantity.

For SCO packages exceeding the $A_2$ quantity, rigorous quantitative determinations must be made as to the activity levels on all accessible and inaccessible surfaces.

In summary, to characterize an SCO:

- The shipper must know the following:
    - Nuclides.
    - $A_2$ fraction within the package.
    - $\beta,\gamma$ and $\alpha$ $A_2$ fraction.

- Collections of contaminated items are SCO, not LSA. For small items, the shipper can use the methodology described in Section 3.3.1 of NUREG 1608.
  ***NOTE: Small means <17 cubic inches ($in^3$).***
- The SCO limits found in Section 173.403 are surface limits and do not incorporate a wiping efficiency, which is assumed to be 10%.
- The wiping efficiency must be accounted for in all SCO determinations. See Section 3.4.5.

LSA versus SCO [NUREG, 4.1.1, 4.1.4]

LSA generally implies activity within a material, while SCO implies activity on a material. There is no size below which an item with surface contamination is not considered to be an SCO. Items greater than 17 $in^3$ are considered discreet for characterization purposes.

A collection of smaller objects can be qualitatively characterized under the provisions in Section 3.4.1 of the NUREG. Some compactable and noncompactable trash (dry active waste) could possibly be either LSA or SCO, depending on its characteristics. For materials such as rags, laboratory wipes, cloth personal protective equipment, and other absorbent material, a reasonable argument can be made that the radioactivity is absorbed throughout the material matrix and is therefore within the material. Nonabsorbent materials such as tools, glassware, and building materials are SCO.

Shipments with Mixed LSA/SCO Contents [NUREG, 6.1.1, 6.1.2]

LSA material and SCO may be mixed together within a package. Each category of material must be appropriately characterized and shown to meet the LSA/SCO definition first.

For packages with an LSA/SCO mixture less than the $A_2$ quantity, the package may be shipped under the LSA proper shipping name. For packages exceeding the $A_2$ quantity, the proper shipping name used should be for whichever material comprises the greatest fraction of the $A_2$ quantity in the package, either LSA or SCO.

Essentially Uniformly Distributed versus Distributed Throughout [NUREG 4.2.2, 4.2.3, 4.2.4]

The LSA allowable concentration levels are based on the activity being essentially uniformly distributed for some LSA-III materials and distributed throughout for all LSA-II materials. In calculating the specific activity, consider the following:

- Nonradioactive, contaminated objects must be classed as SCO and cannot be included in the LSA calculation.
- Encapsulated waste and sealed sources cannot have the activity averaged over the mass of the solidified mass.
- The phrase *estimated average specific activity* means the arithmetic average of the specific activity where the range of specific activity does not vary by more than a factor of 10.
- To assess the estimated average specific activity:
  - For volumes between 0.2 cubic meters ($m^3$) and 1 $m^3$ (roughly 55 gallons to one-half B25 box volume):
    - Divide the volume into at least 5 equal volumes.
    - The specific activity should not vary by more than a factor of 10.
  - For volumes greater than 1 $m^3$, divide it into at least 10 volumes.

For packages with activity less than the $A_2$ quantity, the distribution assessment can be qualitative rather than quantitative if:

- Large amounts of nonradioactive or slightly radioactive material have not been used in the specific activity determination, and
- The material is known not to have a highly stratified or significantly nonuniform distribution of activity.

For packages exceeding the $A_2$ quantity, the quantitative method set forth in Section 4.2.3 of the NUREG should be applied.

## 5.4 ACTIVITY LIMITS, DOSE RATES, AND HAZARD COMMUNITCATON REQUIREMENTS FOR LSA AND SCO SHIPMENTS

Once a material has been found to meet either the LSA or SCO definition, there are additional constraints that must be met. These constraints are detailed in 49 CFR 173.427(a)(1)–(5), as well as in the international regulations. The packaging requirements and domestic exceptions for exclusive use shipments are detailed in Sections 173.427(a)(6) and 173.427(b) and (c). The domestic exceptions do not apply for air and water shipments made under the international regulations. The constraints on LSA/SCO shipments are as follows:

- The external dose rate must not exceed 1 rem/hr at 3 meters from the unshielded material. Material that exceeds this dose rate must be packaged in NRC- or DOE-approved packaging that passes the hypothetical accident tests.
- A conveyance limit is specified in Table 5 of Section 173.427.
- The material must be either nonfissile or fissile-excepted under Section 173.453.
- Packages must meet the contamination control limits in Section 173.443 and the dose limits in Section 173.441.

### Radiation Level Limit for Unshielded LSA Material and SCO

Section 173.427(a)(1) specifies that the quantity of LSA material or SCO in a single authorized package must be restricted so that the external radiation level from the unshielded material does not exceed 10 mSv/hr (1 rem/hr) at 3 meters. This radiation dose rate limit restricts the permitted quantity of LSA material and SCO in one package to the same external radiation hazard that is associated with a non-LSA/SCO shipment. Essentially, the external radiation from unshielded LSA material or SCO in a package will not exceed the dose rate that would result if a special form source was 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 the dose rate would not exceed the limit of 1 rem/hr at 3 meters even without any shielding. If it exceeds the limit, the material may no longer be considered LSA or SCO, and it will require Type B packaging. Shippers of LSA/SCO material will find useful information concerning methodologies for determining activity and unshielded radiation dose rates for LSA/SCO shipments in NUREG-1608.

LSA material or SCO that exceeds the 1 rem/hr at 3 meters dose restriction in Section 173.427(a)(1) must be offered in packaging approved by the NRC under the provisions in 10 CFR 71. LSA material or SCO that cannot qualify as fissile-excepted must be packaged in authorized fissile material packaging.

### Conveyance Activity Limits for LSA/SCO

The regulations place restrictions on the total activity of some LSA material and all SCOs transported in a conveyance. An activity restriction of 100 $A_2$ per conveyance applies to all SCOs and to LSA-II and LSA-III materials that are combustible solids or are in liquid or gaseous form. These conveyance limits are found in Table 5 of Section 173.427.

### Hazard Communication

Domestic LSA/SCO shipments that are conducted as exclusive use shipments are excepted from the marking and labeling requirements in Part 172. However, the packages and unpackaged material must be marked with the words *Radioactive-LSA* or *Radioactive-SCO* and *RQ*, as appropriate. With the exception of unconcentrated U or Th ores, the vehicle must be placarded. There is no exception for shipping papers. Air and water shipments of LSA/SCO have no exceptions for shipping papers, marking, labeling, or placarding.

## 5.5 PACKAGING REQUIREMENTS FOR LSA MATERIAL AND SCO

Starting in the HMT, the proper shipping names (including LSA or SCO) are referenced in Section 173.427 in Columns 8B and 8C. Column 8A refers to Sections 173.421, 173.422, and 173.428. Therefore, LSA/SCO material that also meets the excepted packaging requirements can be shipped as limited quantity or empty packaging, as appropriate. The choice of packaging will be determined by the LSA/SCO category, the mode of transport, whether domestic or international carriage is involved, and economic factors.

Industrial packaging (IP) is authorized for LSA/SCO in both the domestic and international regulations. The DOT Specification Type A packaging is authorized for domestic transportation only. Excepted packaging is only authorized for domestic transportation, with the contents restricted to no more than Type A quantities and shipped as exclusive use. LSA-I liquids may be offered in the bulk packages listed in Section 173.427(b)(5).

Section 173.427(b) authorizes the following packages for shipment of LSA material and SCO:

- For domestic transportation only, excepted packaging is authorized when it is transported in an exclusive use vehicle and does not exceed an $A_2$ quantity in each package.

  *NOTE: The packaging must meet the "General Design Requirements" of Sections 173.410 and 173.24.*

- For domestic transportation only, DOT Specification 7A (DOT 7A) Type A packaging may be used. The package must prevent the loss or dispersal of the radioactive contents and maintain the radiation shielding properties during normal conditions of transport, which include rough-handling conditions. The tests are specified in 49 CFR 173.465 and include a water spray test, drop test, penetration test, and stacking test.

- For both domestic and international transportation, IP-1, IP-2 or IP-3 may be used. IP-1 must meet the general packaging requirements of Section 173.410 and is, therefore, equivalent to excepted packaging. Each IP-2 must meet the general design requirements of an IP-1 and the free drop test and stacking (compressive load) test specified for Type A packaging. Each IP-3 is identical to the Type A packaging authorized for solid Type A quantities of radioactive material.

  For IP-1, IP-2, and IP-3, the IP category required for LSA material or SCO is related to the potential radiological hazard of the material to be transported. LSA-II and LSA-III material with radiological hazards greater than LSA-I require the more durable IP-2 and IP-3, while the LSA-I material with lower radiological risk can be shipped in the lower-durability IP-1.

  This illustrates the general principle that contents posing a greater radiological risk are required to be transported in more durable packages. In addition, if released from its package, radioactive material in liquid form generally presents greater radiological risks than material in solid form. Therefore, LSA material in liquid form requires more durable packaging than solid LSA material.

  Similarly, nonexclusive use shipments do not have the controls during transport that may exist for exclusive use shipments. Thus, nonexclusive use LSA shipments require packaging of greater integrity than is required for exclusive use shipments. The categories

of industrial packages required for different LSA material and SCO shipped under different transportation conditions are provided in Table 6 of Section 173.427.

- Any Type B, B(U), or B(M) package, as authorized in Section 173.416. Type B packages are usually used for material other than LSA and SCO. However, they may be used if the radioactivity and physical form of the LSA material or SCO to be shipped are such that the material 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 in Section 173.416. For NRC- and DOE-certified Type B packages, the authorized contents are described in the NRC certificate for each package.

Under Section 173.427(c), LSA-I and SCO-I solids may be transported unpackaged under the following conditions:

- The material must be transported in a manner that ensures no release of contents from the conveyance and no loss of shielding under normal conditions of transport.
- Except for SCO-I items with specified low contamination levels, the shipment must be exclusive use.
- For SCO-I items with removable contamination above the specified limits, measures must be taken to ensure that the radioactive material is not released inside the conveyance or to the environment.

Items such as piping from decommissioning projects should have the ends plugged, capped, or crushed to prevent the release of radioactive material to the conveyance.

For air and water shipments, LSA/SCO shipments must be packaged in IP-1, IP- 2, or IP-3, as appropriate. Unpackaged LSA/SCO material is prohibited by air. None of the domestic exceptions for packaging, marking, and labeling appear in the IATA/IMDG regulations.

Typical Packages for Radioactive Waste Shipped as LSA or SCO

The following are typical packaging and shipping configurations for material classified as LSA or SCO.

*Intermodal Container* – Depending on the contents or other packaging, it may be a conveyance, bulk packaging, excepted, or IP.
Dimensions: 2.4 meters by 2.6 meters by 6 meters or 12 meters
Weight: 18,000 kg
Contents: Type A package, IP, or excepted package, unpackaged LSA-I or LSA-II material, or unpackaged SCO
Radionuclides: Nonfissile, fissile-excepted, or isotopes from research or production facilities

*Shielded LSA Cask* – Type A, IP-2, and IP-3.
Dimensions: 1.9 meters outer diameter by 2.2 meters
Weight: 26,500 kg
Contents: Irradiated solids, dewatered resins, and other solids meeting the LSA and SCO definitions
Radionuclides: Nonfissile or fissile-excepted radionuclides in quantities less than or greater than $A_2$ and not exceeding 1 rem/hr at 3 meters

*Steel Drum* – Depending on content and inner packaging, it may be an excepted packaging, Type A, or IP-1, IP-2, or IP-3.
Dimensions: 0.7 meters outer diameter by 0.9 meters
Weight: 290 kg
Contents: May range from limited quantities to LSA-I, LSA-II, and LSA-III and SCO-I and SCO-II
Radionuclides: May be nonfissile or fissile-excepted in quantities from MBq to TBq (mCi to Ci)

*Metal Box* – Excepted packaging, Type A, or IP
Dimensions: 0.9 meters by 1.2 meters by 2.4 meters
Weight: 3600 kg
Contents: LSA-I, LSA-II, or LSA-III; SCOs
Radionuclides: May be nonfissile or fissile-excepted in quantities from Bq to TBq (mCi to Ci)

## 5.6 REVIEW QUESTION SET 6

1. What types of packaging are authorized for LSA material and SCO?

   IP
   Excepted Packaging
   DOT 7A
   Certificate Type A/B
   Unpackaged

2. What markings are required on LSA/SCO packages offered:

   - By highway, as exclusive use (Type A quantity of material):

     *Radioactive-LSA* or *Radioactive-SCO*; RQ (if applicable)

   - By air:

     No Marking Exceptions (IATA 10.7.1.3) PSN; UN ID number; Names/Addresses; Gross Weight (>50 kg); IP-1, -2, or -3, as appropriate

   - By highway, nonexclusive use:

     No Marking Exceptions; Full Marking per Section 172.301-310, et al.

   - By rail, Type B quantity:

     No Marking Exceptions; Full Marking per Section 172.301-310, et al.

3. When must LSA/SCO shipments be placarded?

   When the RADIOACTIVE YELLOW-III label is applied or it is exclusive use under Section 173.427(a)(6)(v)

4. When must NRC-approved packaging be used for LSA/SCO shipments?

   When >1 rem/hr at 3 meters from unshielded material

5. Under what conditions can unpackaged SCO be shipped?

   Section 173.427(c)

6. A 55-gallon drum (gross weight is 90.8 kg), containing three cartridge filters, each weighing 4.53 kg. Each filter contains the following nuclides/activity distributed throughout the filter media:

$^{60}Co$ 0.018 TBq $^{90}Sr$ 0.011 TBq $^{137}Cs$ 0.015 TBq

Determine if the drummed filters can be shipped as an LSA-I or LSA-II material. The dose rate at 3 meters from the unshielded filters is less than 1 rem/hr.

**We determine the corresponding $A_2$ and exempt concentration limits to be the following:**

| | $A_2$ (TBq) | Exempt Concentration Limit (Bq/g) |
|---|---|---|
| $^{60}Co$ | 0.4 | 10 |
| $^{90}Sr$ | 0.3 | 100 |
| $^{137}Cs$ | 0.6 | 10 |

**Calculating our total activity and concentrations for the 3 filters:**

| | Activity (TBq) | Concentration (TBq/g) |
|---|---|---|
| $^{60}Co$ | 0.054 | 4 E-6 |
| $^{90}Sr$ | 0.033 | 2.4 E-6 |
| $^{137}Cs$ | 0.045 | 3.3 E-6 |

LSA-I Limit: 30 X Exempt Concentration Value

Look at: $^{60}Co$: 30 (10 Bq/g) = 300 Bq/g = LSA-I Limit for $^{60}Co$

We have: 4 MBq/g = 4 E6 Bq/g

***This exceeds the LSA-I limit, so there is no need to evaluate the mixture further.***

LSA-II Limit = 10-4($A_2$/g)

We can evaluate the mixture using the sum of the ratios equation:

$$\Sigma\ [\text{Nuclide Concentration}/\text{LSA-II Limit}] \leq 1$$

Σ [4 E-6/0.4 E-4] + [2.4 E-6/0.3 E-4] + [3.3 E-6/0.6 E-4] = 0.1 + 0.08 + 0.055 = 0.24

**So, it is okay as LSA-II.**

*Alternatively, you could calculate an $A_2$ value for the mixture and apply the LSA-II limit and compare against the shipping value:*

$A_2$ = 1/Σ [(Nuclide Activity/Total Activity)/$A_2$] see Section 173.433 (d)(5)

This equation can be rewritten as: $A_2$ = Total activity/Σ (Nuclide Activity/$A_2$)

**TOTAL ACTIVITY PER FILTER: 0.044 TBq LSA-II limit = $10^{-4}$ $A_2$/g = 0.4 E-4 TBq/g**

**For our mixture: $A_2$ = 0.044 TBq / Σ [(0.018/0.4) + (0.011/0.3) + (0.015/0.6)]**
**= 0.044/(0.045 + 0.037 + 0.025) = 0.044/0.11 = 0.4 TBq**

**Concentration for each filter = 0.044/4,530 g = 9.7 E-6 TBq/g Therefore, each filter qualifies as LSA-II, and the contents of the drum will meet LSA-II.**

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# CHAPTER 6
# FISSILE MATERIAL

OBJECTIVES

- IDENTIFY FISSILE MATERIAL.
- DETERMINE FISSILE EXEMPTIONS.
- DETERMINE APPROPRIATE PACKAGING FOR FISSILE MATERIAL.
- DETERMINE AND USE THE CSI.
- DETERMINE THE APPLICABLE HAZARD COMMUNICATION AND CONTROLS FOR FISSILE MATERIAL SHIPMENTS.

## 6.1 INTRODUCTION

In addition to the other hazards associated with all radioactive material, fissile material has the potential to produce a criticality event that would result in significant releases of radiation and thermal heat. Prevention of this occurrence is achieved by selecting the appropriate packaging, applying additional controls on the shipment, and communicating those controls to the transport worker.

The DOT regulates materials as being fissile if they meet the fissile material definition in Section 173.403. *Fissile material* means $^{239}Pu$, $^{241}Pu$, $^{233}U$, $^{235}U$, or any combination of these radionuclides. The definition applies to the nuclides themselves and not to the material containing them. For example, fissile mass restrictions in the regulations apply to the mass of $^{235}U$ and not to the mass of U metal containing the $^{235}U$.

There are other nuclides that are fissionable. The DOT only regulates as fissile materials those materials that are capable of having a sustained criticality by accumulation of mass alone. Therefore, the fissile material definition does not apply to unirradiated natural U, unirradiated depleted U, natural U, or depleted U that has been irradiated in thermal reactors only. (See the definitions for *unirradiated uranium* and *thorium* in Section 173.403.)

Identifying and choosing fissile material packaging is a relatively straightforward process, but there are multiple regulatory sections that must be addressed to complete this process. Care must be taken to ensure that all of the requirements are met.

As with all radioactive material shipments, the starting point for determining the packaging requirements is Column 8 in the HMT of 49 CFR. The entries for Type A and Type B packaging that include the word *fissile* in the proper shipping name refer to Section 173.453 for packaging exceptions in Column 8A. In Column 8B, the reference is Section 173.417.

## 6.2 FISSILE MATERIAL EXCEPTIONS

Section 173.453 details the fissile material exceptions. If the material meets the requirements of this section, it is not excepted from the inherent property of being fissile, but it is excepted from the packaging and controls that are required for fissile material. This is reasonable, since what differentiates fissile material from other radioactive material is the fact that it can, under certain conditions, become critical and release heat and radiation. This is not desirable while transporting the material, so shipments of fissile material have controls (mass configuration, accumulation, etc.) to prevent criticality events from occurring.

Section 173.453 establishes the mass or concentration limits below which any number of packages with this material could be transported together without the possibility of a criticality occurring. Therefore, no other controls (found in Sections 173.457 and 173.459) are needed. Paragraphs (a) through (f) of Section 173.453 are independent, and only one paragraph needs to be met to take the fissile exception.

Section 173.453(a) allows for up to 2 g of fissile material in a package. This exception is frequently used for analytical samples and some laundry shipments.

Section 173.453(b) allow for up to 15 g of fissile material in a package. The mass of the packaging may be used to meet the 200:1 ratio of nonfissile to fissile mass.

Section 173.453(c) does not state a fissile mass restriction for a package, but it states that the materials must have certain nonfissile to fissile mass ratios. When evaluating the ratio, only mass that has the fissile mass interspersed, or distributed, within it, may be used to meet the 2000:1 ratio. See the Federal Register dated January 26, 2004, pages 3747–3749, and the NRC letter of clarification dated October 2, 2007, that was issued to Energy*Solutions*. The NRC letter of clarification is available through the ADAMS database at www.nrc.gov.

For packaging purposes, fissile-excepted material is treated the same as any other nonfissile radioactive material. The full range of packaging that is available for nonfissile radioactive material is available for fissile-excepted material. Fissile-excepted material might meet the limited quantity or LSA/SCO definitions and, therefore, be shipped under these proper shipping names in excepted packaging. Alternatively, any other proper shipping name with appropriate Type A or Type B packaging could be used.

All of the fissile exceptions in Section 173.453 are summarized below:

- Not more than 2 g fissile material per package.
- Package with not more than 15 g fissile material, provided there is a 200:1 g ratio of solid nonfissile material (excluding lead, Be, graphite, and deuterium-enriched hydrogenous material that is present) for every g of fissile material. The mass of the packaging may be included in determining the 200:1 ratio.
- Fissile material commingled with solid nonfissile material such that the following criteria are met: (The NRC has stated in a letter of clarification that contaminated objects could meet the "commingled" criteria.)
    - 2000:1 ratio nonfissile g to fissile g.
    - ≤180 g fissile material distributed within 360 kg of contiguous nonfissile material (excluding lead, Be, graphite, and deuterium-enriched hydrogenous material that is present).
    - Only mass that has fissile material distributed in it (i.e., fissile mass is interspersed with it) may be used to calculate the 2000:1 ratio. ***NOTE: The packaging mass may not be included when determining the ratios in Section 173.453(c).***
- U enriched ≤1% (restrictions on Pu and $^{233}$U content).
- Liquid uranyl nitrate enriched ≤2% (restrictions on Pu and $^{233}$U content).
- A package with Pu mass less than 1 kg, with $^{239}$Pu and $^{241}$Pu not more than 20% by mass. ***NOTE: This paragraph is not applicable for U that may have trace amounts of Pu present.***

***NOTE: The fissile material exception requirements are different in the ICAO regulations and the IMDG Code. See Section 10.3.7.2 in the IATA regulations. The DOT fissile exceptions must be met when shipping by air under the IATA regulations. See USG 01 and Section 175.703(b).***

## 6.3 FISSILE MATERIAL PACKAGING AND SHIPPING REQUIREMENTS

All fissile material shipments, unless fissile excepted under Section 173.453, must meet the requirements in Sections 173.457 and 173.459. The requirements for fissile material shipments include the following:

- Packages must be assigned a CSI and TI.
- The dose rates for packages and conveyances must meet Section 173.441.
- An individual package CSI cannot exceed 50, unless it is offered by exclusive use.
- The total CSI per conveyance is limited to 50, unless it is offered by exclusive use.
- Mixing fissile material packages with other Class 7 material is allowed only if the TI of any package is ≤10 and the CSI of any package is ≤50.

Authorized fissile material packaging is provided in Section 173.417. This a rather long section, but it is logically laid out with all of the Type A packaging listed in paragraph (a) and all of the Type B packaging listed in paragraph (b).

Except for DOT specification packaging (e.g., DOT 7A, DOT-20PF, DOT-21PF), all other types of Type A and Type B fissile packaging in use have been certified by the NRC as indicated in Sections 173.417(a)(4) and (b)(3) or by DOE pursuant to the authority of Section 173.7(d). Fissile packages of foreign origin are subject to the same DOT requirements as nonfissile Type B packages, and they must be revalidated by the DOT before they can be used for import or export of shipments.

The fissile packaging choices are discussed below. (The packaging and shipment of fissile and nonfissile $UF_6$ are discussed in Chapter 10 of this manual.)

### Type A Fissile Packaging Overview

- Type A packaging listed in Section 173.415. (The mass restrictions for these packagings are in listed in 10 CFR 71.22).
- NRC- and DOE-approved Type A or B packaging.
- IAEA-approved packaging (domestic use is restricted to import/export).
- DOT 7A cylinders for $UF_6$ heels.
- DOT 20PF-1, 20PF-2, 20PF-3; DOT 21PF-1A, 21PF-1B; 21PF-2 (for $UF_6$).

### Type B Fissile Packaging Overview

- NRC- and DOE-approved Type B packaging.
- IAEA-approved packaging (restricted domestic use).
- DOT 20PF-1, 20PF-2, 20PF-3; DOT 21PF-1A, DOT 21PF-1B (for $UF_6$).

In all cases, it is important that the fissile material contents comply with the approved contents for the packaging. Criticality safety can be sensitive to the quantity, type, form, and configuration of the fissile material, any fixed neutron poisons, and/or other nonfissile material included in the contents. Inclusion of fissile material or other radionuclides not authorized for the packaging can affect the criticality safety. For example, replacing $^{235}U$ with $^{233}U$ can yield a higher neutron multiplication factor. Similarly, placement of the same quantity of fissile material in a heterogeneous or homogenous distribution can significantly affect the multiplication factor. A heterogeneous lattice arrangement provides a higher reactivity for low enriched U systems than a homogenous distribution of the same quantity of material.

Packaging selection is primarily a process that compares the material being shipped against the authorized contents for the particular packaging. This involves using the paragraphs and tables in 49 CFR or the relevant sections in a Certificate of Compliance. When using a DOT 7A packaging under Section 173.417(a)(1)(i), the shipper must use Subpart C of 10 CFR 71. Some specifics regarding the more popular choices of fissile packaging are discussed on the following pages.

### DOT 7A Type A Packaging

Use of DOT 7A Type A packaging is authorized for Type A quantities of fissile material under Section 173.417(a)(1)(i). The packaging content limits are provided in 10 CFR 71, Subpart C. Although written for NRC licensees, DOE contractors may use the packaging in this subpart, subject to the stated requirements.

The mass restrictions for the DOT 7A packaging are stated in Section 71.22. Restrictions are also provided for the allowable mass of Be, graphite, and hydrogenous material enriched with deuterium. An equation in Section 71.22(e) is used to calculate the CSI for the package. Table 71-1 in Section

71.22 is used for mixed fissile nuclides ($^{233}U$ and/or Pu >1% present) and for enrichment greater than 24%, as well as for unknown enrichment. According to Section 71.22(5)(iv), when accounting for moderating effectiveness, the polyethylene used for the packaging or wrapping does not have to be considered. See also the footnote to Table 71-1.

When using Table 71-2, do not use linear interpolation for masses in between the values. This is not a linear relationship. Instead, use the higher value stated in the table. For insight into how the values were determined, see NUREG/CR-5342, *Assessment and Recommendations for Fissile-Material Packaging Exemptions and General Licenses Within 10 CFR Part 71*. This is available on the internet at: http://rampac.energy.gov//NRCinfo/NUREG_5342.pdf. Tables 71-1 and 71-2 are shown in Figure 6-1.

TABLE 71–1—MASS LIMITS FOR GENERAL LICENSE PACKAGES CONTAINING MIXED QUANTITIES OF FISSILE MATERIAL OR URANIUM-235 OF UNKNOWN ENRICHMENT PER §71.22(e)

| Fissile material | Fissile material mass mixed with moderating substances having an average hydrogen density less than or equal to $H_2O$ (grams) | Fissile material mass mixed with moderating substances having an average hydrogen density greater than $H_2O$[a] (grams) |
|---|---|---|
| $^{235}U$ (X) | 60 | 38 |
| $^{233}U$ (Y) | 43 | 27 |
| $^{239}Pu$ or $^{241}Pu$ (Z) | 37 | 24 |

[a] When mixtures of moderating substances are present, the lower mass limits shall be used if more than 15 percent of the moderating substance has an average hydrogen density greater than $H_2O$.

TABLE 71–2—MASS LIMITS FOR GENERAL LICENSE PACKAGES CONTAINING URANIUM-235 OF KNOWN ENRICHMENT PER §71.22(e)

| Uranium enrichment in weight percent of $^{235}U$ not exceeding | Fissile material mass of $^{235}U$ (X) (grams) |
|---|---|
| 24 | 60 |
| 20 | 63 |
| 15 | 67 |
| 11 | 72 |
| 10 | 76 |
| 9.5 | 78 |
| 9 | 81 |
| 8.5 | 82 |
| 8 | 85 |
| 7.5 | 88 |
| 7 | 90 |
| 6.5 | 93 |
| 6 | 97 |
| 5.5 | 102 |
| 5 | 108 |
| 4.5 | 114 |
| 4 | 120 |
| 3.5 | 132 |

TABLE 71–2—MASS LIMITS FOR GENERAL LICENSE PACKAGES CONTAINING URANIUM-235 OF KNOWN ENRICHMENT PER §71.22(e)—Continued

| Uranium enrichment in weight percent of $^{235}U$ not exceeding | Fissile material mass of $^{235}U$ (X) (grams) |
|---|---|
| 3 | 150 |
| 2.5 | 180 |
| 2 | 246 |
| 1.5 | 408 |
| 1.35 | 480 |
| 1 | 1,020 |
| 0.92 | 1,800 |

[69 FR 3786, Jan. 26, 2004; 69 FR 58038, Sept. 29, 2004]

**Figure 6-1. Tables 71-1 and 71-2 on Mass Limits in Section 71.22**

Title 10 CFR Part 71.23 contains provisions for PuBe special form sources authorized for shipment in DOT 7A packaging. When using DOT 7A packaging, the shipper is required to maintain on file for at least 1 year after shipment the complete documentation of the tests and an engineering evaluation or comparative data showing that the package used met the Type A specification.

***NOTE: An additional drop test is required under Section 173.465(c)(2) when there are fissile contents. Currently, there are a limited number of DOT 7A Type A packages that have passed the additional drop test in Section 173.465(c)(2) and are qualified for fissile contents.***

DOE has a database with DOT 7A testing and evaluation information available for use on the internet at the DOE Radioactive Material Packaging homepage at http://rampac.energy.gov. Care should be taken when using this database to ensure that all the required testing data is present. Additional documentation or analysis may be needed to meet the requirements in Section 173.415(a).

In 10 CFR 71.22(e), there is an equation to calculate the CSI for the package. The values for X, Y, and Z are the allowable mass limits for $^{235}U$, $^{233}U$, and Pu, respectively, as found in either Table 71-1 or Table 71-2, as appropriate. The equation is shown in Figure 6-2 on the following page.

$$CSI=10\left[\frac{\text{grams of } ^{235}U}{X}+\frac{\text{grams of } ^{233}U}{Y}+\frac{\text{grams of Pu}}{Z}\right]$$

**Figure 4. CSI equation for use with the DOT 7A Type A Packaging**

## NRC- and DOE-Approved Packaging

The types of packaging that have been certified for fissile contents by either the NRC or DOE have a Certificate of Compliance issued by the respective entity. The certificate details the authorized contents for the package and any controls, such as an assigned CSI. Figure 6-3 below is extracted from a packaging Certificate of Compliance and shows the CSI in the far right-hand column.

5.(b) Contents (continued)

(3) Unirradiated uranium as solid metal. The uranium may be of any enrichment. The maximum H/U must consider all sources of moderation in the inner vessel.

| Fissile Material | Maximum H/U | Maximum Fissile Mass per Package (kg) | Minimum Transport Index (Criticality Safety Index) |
|---|---|---|---|
| U-235 | 3 | 9.0 | 2.5 |
| U-235 | 3 | 1.6 | 0.5 |
| U-235 | 20 | 4.0 | 2.0 |
| U-233 | 20 | 0.5 | 1.8 |

NUCLEAR REGULATORY

**Figure 6-2. Example of CSI in a package Certificate of Compliance**

NRC-approved packages may be used by DOE contractors if either they or DOE has registered with the NRC as a user of the certificate. (See the registration requirement in Section 173.471(a) and DOE Guide 460.1-1.) Shippers must have a current copy of the Certificate of Compliance and comply with all the provisions of the certificate. Shipments can still be made if the expiration date has passed if the certificate is under timely renewal in accordance with 10 CFR 71.38. Packaging approved by the NRC or DOE and authorized for fissile contents has an AF or BF designation in the approval (e.g., USA/9196/AF-96 and USA/9975/B(M)F-85 (DOE)).

## Typical Fissile Material Packages

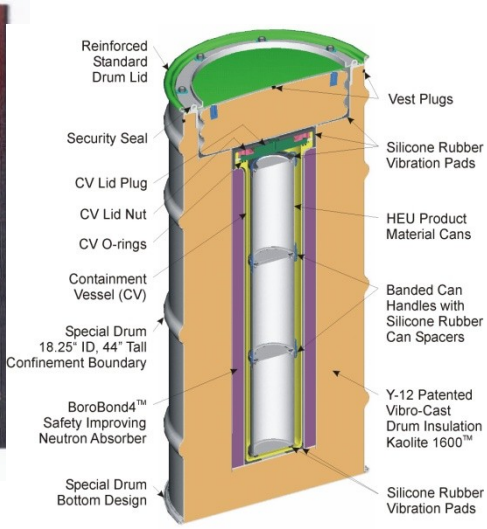
The following are some typical packages used in transporting fissile radioactive material. The descriptions of the illustrated packages show the approximate dimensions, weight, and contents of the packages.

*$UF_6$ Overpack* – Bare 30-inch cylinder for $UF_6$ beside the overpack
Dimensions: 1.1 meters outer diameter by 2.3 meters
Weight: 3700 kg
Contents: $UF_6$ enriched to 5% $^{235}U$, 0.2 TBq (6 Ci).

*Research Reactor Spent Fuel Cask* (with impact limiters) –
Dimensions: 1.8 meters outer diameter by 3.3 meters
Weight: 15,200 kg
Contents: Highly enriched U, mixed fission products, 600 TBq (16,000 Ci).

*ES-3100* – Replacement for the DOT Specification 6M
Contents: Enriched U in solid form

ES-3100 containment vessel



## 6.4 REVIEW QUESTION SET 7

1. List the nuclides that are considered to be fissile by the DOT.

   $^{233}U$, $^{235}U$, $^{239}Pu$, and $^{241}Pu$

2. What percentage, by weight of $^{235}U$ is in:

   - Natural U: 0.72
   - Depleted U: <0.72 Section 173.403 definition of U
   - Enriched U: >0.72

3. If the conditions in Section 173.453 are met, then:

   - What is the material/package excepted from?

     Fissile Packaging Standards
     Criticality Controls

   - What proper shipping name should be used to make the shipment?

     Any appropriate, nonfissile proper shipping name

4. What section of the regulations specifies the maximum mass of fissile material authorized in a DOT 7A packaging?

   10 CFR 71.22

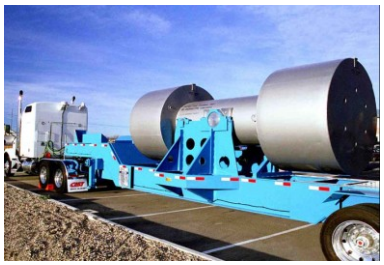
5. When using an NRC- or DOE-certified packaging, where are the CSI and other controls and restrictions found?

   In the packaging Certificate of Compliance

# CHAPTER 7
# PACKAGING

OBJECTIVES

- UNDERSTAND PACKAGING STANDARDS FOR ALL HAZARDOUS MATERIALS.
- UNDERSTAND HOW TO SELECT PROPER PACKAGING FOR ALL HAZARDOUS MATERIALS.
- UNDERSTAND QUALITY ASSURANCE AND QUALITY CONTROL REQUIREMENTS FOR PACKAGING.
- UNDERSTAND TESTING AND PERFORMANCE REQUIREMENTS FOR PACKAGING.
- UNDERSTAND THE RESPONSIBILITIES FOR PACKAGING MANUFACTURERS AND USERS.



## 7.1 INTRODUCTION

Hazardous material transportation has been regulated in the United States for over 100 years. The early regulations codified from common law the responsibilities of shippers and common rail carriers. Generally, these obligations were for the shipper to know the hazards of the material, to package it safely, and to communicate the hazards to the carrier. The common carrier's primary responsibility was to assure the material was delivered undamaged.

The original focus was on explosive material and then on what was called *other dangerous articles*, which included flammables, corrosives, compressed gases, and poisonous material. The regulations have evolved into a much more complex system today, but these original concepts remain, with the emphasis on effective containment of material in transit and hazard communication to involved personnel.

In 1966, the DOT received the hazardous materials regulatory authority that had been previously vested with the Interstate Commerce Commission, the Federal Aviation Administration, and the Coast Guard. General packaging issues are now managed by the DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA).

There are also a number of private groups that establish standards or specifications for packaging. The most common of these groups are rail and highway carriers. By tariff, rail (Uniform Freight Classification), and truck (National Motor Freight Classification), the common carriers establish the packaging standards that are applicable to nonhazardous material. Other carriers, such as the USPS, have established packaging standards in conjunction with the National Safe Transit Association. The packaging specifications from these groups relate to the shippers being able to successfully file claims for loss or damage to their freight. The carrier's liability for claims is generally contingent on the shipper having used carrier-recommended packaging. Other nongovernmental bodies with packaging standards include the Association of American Railroads, the American Society for Testing Materials, and the American Society of Mechanical Engineers (ASME). These standards may be incorporated by reference in other requirements, contracts, and government codes.

All hazardous material packages must meet the general packaging requirements of 49 CFR 173.24. These requirements lay the foundation for all types of packaging and require that packages be ". . . designed, constructed, maintained, filled, its contents so limited, and closed that under conditions normally incident to transportation . . . there will be no identifiable . . . release of hazardous materials to the environment . . . effectiveness of the packaging will not be substantially reduced . . ."

The regulations address all types of packaging. Included are single and combination nonbulk packages, such as fiberboard boxes and metal drums and cylinders. Bulk packages include tank cars, cargo tanks, and portable tanks.

## 7.2 PACKAGING PERFORMANCE STANDARDS

The current hazardous material packaging standards are based largely on the international standards established by the UN Committee of Experts on the Transportation of Dangerous Goods. These standards require the use of performance-oriented packaging (i.e., packaging designed and tested to pass specific tests that simulate the stresses and insult that could occur during conditions of normal transport).

This system allows for greater flexibility in packaging material and design as opposed to the old specification system found in the earlier regulations. A small number of specification packagings still exist in 49 CFR 178 and 179 (some gas cylinders, portable tanks, cargo tanks, tank cars, and a

few radioactive material packages), and their use is authorized under 49 CFR 173.23. The standards for performance-oriented packaging are provided in Part 178, Subpart L. Packages and their associated performance levels are grouped into packing groups that reflect the hazard associated with the authorized contents: low, medium, or high hazard. The testing requirements for nonbulk packages are located in Part 178, Subpart M. As an example, review Section 178.603(e)(1) and compare the required drop test heights for Packing Groups I, II, and III.

### What is Performance-Oriented Packaging?

Performance-oriented packaging is based on performance standards developed in the form of recommendations by the UN Committee of Experts on the Transport of Dangerous Goods (called the UN Recommendations). The UN standards have general requirements for materials, construction, and maximum capacity. The containers must pass or be capable of passing a series of performance tests before they are authorized for the transport of hazardous materials.

Packaging requirements are based on the packing group of the material, its vapor pressure, and the chemical compatibility between the package and the hazardous material. Nonbulk packaging standards are based on a number of performance tests. In addition to the performance-oriented tests recommended by the UN, a vibration test for nonbulk packaging is required domestically.

Reuse of plastic and metal drums is based on minimum thickness requirements. This compensates for the lack of performance tests in the UN standards for puncture resistance, abrasion resistance, and metal fatigue. Package manufacturers must provide written notification to customers of any specification shortfalls or steps to be taken to conform to the applicable specification. Performance tests for UN packaging, including design qualification tests and periodic retests, are included in Part 178.

### Packing Groups

The packing group designated in the HMT Table, Column 5, indicates the degree of danger presented by the material. The shipper is responsible for determining the appropriate packing group.

| Packing Group | Degree of Danger |
|---|---|
| I | Great |
| II | Medium |
| III | Minor |

If more than one packing group is indicated for an entry in the HMT, the packing group for the hazardous material is determined using the criteria in 49 CFR 173, Subpart D. For example, Section 173.121 details the designation of packing groups for Class 3 material based on flash point and initial boiling point.

## 7.3 PACKAGING RESPONSIBILITIES

General requirements are contained in 49 CFR 171.2(g). No person may represent, certify, mark, sell, or offer a packaging or container as meeting the requirements of the HMR unless the packaging or container is manufactured, fabricated, marked, maintained, reconditioned, repaired or retested, as appropriate, in accordance with the HMR. The responsibilities for packaging manufacture and testing are provided in Section 178.2.

### Packaging Manufacturer

It is the responsibility of the packaging manufacturer to assure that each package is capable of passing the prescribed tests. The following tests are performed, as appropriate, for each type of packaging:

- Drop Test (Section 178.603)
- Leakproofness Test (Section 178.604)
- Hydrostatic Pressure Test (Section 178.605)
- Stacking Test (Section 178.606)
- Cooperage Test for Bung-Type Wooden Barrels (Section 178.607)
- Chemical Compatibility Test for Plastic Receptacle (Section 178.608)
- Vibration Standard (Section 173.24a(a)(5))

***NOTE: Each section must be consulted to determine the applicable test for each type of container.***

Packaging testing consists of the following:

- Design Qualification Testing (Section 178.601(c)(1))
- Periodic Retesting (Section 178.601(c)(2))
- Production Testing (Section 178.601(c)(3))
- Frequency of Periodic Testing (Section 178.601(e))
- Test Samples (Section 178.601(f))

The person who manufactures packaging subject to the HMR requirements is responsible for ensuring that it is in conformance with the requirements contained in 49 CFR 178. When packaging is required to be marked with a UN standard or DOT specification, the packaging must meet all the requirements of the regulation, including testing. The manufacturer's marking requirement is contained in 49 CFR 178.503.

The packaging identification code consists of the following:

- Type of packaging.
- Material of construction.
- Category of packaging, when appropriate.
- A letter identifying the performance standard:
  - X – Meets Packing Group I, II, and III tests.
  - Y – Meets Packing Group II and III tests.
  - Z – Meets only Packing Group III tests.
- Specific gravity or mass. The specific gravity for packaging without an inner lining designed to hold liquids is rounded down to the first decimal for nonviscous liquids having a specific gravity greater than 1.2.
- Maximum gross mass in kg for viscous liquids, solids, or inner packaging.
- A letter "S" for packaging intended only for solids or inner packaging, with the test pressure in kilopascals of the hydrostatic test pressure.
- The last two digits of the year of manufacture.
- The letters indicating the country of origin (e.g., USA).
- The name and address or symbol of the person applying the marks.

The manufacturer or person certifying that the packaging is in compliance with Part 178 must inform in writing each person to whom the packaging is transferred of all the requirements of Part 178 not met at time of transfer and all actions that need to be taken for the packaging to conform to requirements of Part 178. The written statements must be retained by the manufacturer for at least 1 year in accordance with 49 CFR 178.2(c). When filling a packaging with hazardous material, the shipper must comply with these written instructions.

### Packaging User Responsibilities

It is the shipper (the user of the packaging) who has overall responsibility to ensure that the transportation package is in full compliance with the regulations. These responsibilities are generally delineated as:

- Use.
- Reuse and maintenance.
- Design.
- Fabrication and/or procurement.
- Testing, analysis, and evaluation.
- Quality assurance and documentation.

The shipper might not perform all of the above functions, but it has the responsibility to ensure that each function performed is properly done. The shipper is the one who uses the packaging and is, therefore, responsible to make sure that it is used in accordance with its design. The design will dictate many of the limits placed on the contents, such as mass and physical form.

There is a fundamental relationship between the contents and the packaging that bears directly on the ability of the completed package to pass the required tests. For example, one type of packaging may be adequate for a lightweight, relatively soft, solid content. This same type of packaging may be incapable of passing the required drop tests when filled with a hard, high-density content.

In addition, the shipper must ensure the chemical compatibility of the contents with the primary containment. This is addressed in the packaging design. The shipper must also ensure that the package is properly loaded and closed. Some designs involve assembly of numerous components and specific closure requirements. Failure to adhere to the design requirements will cause the package to be out of specification and could result in unacceptable releases of material during transport.

Packaging may be designed for either a single trip or multiple trips. Each time the package is offered, it is the shipper's responsibility to ensure that the design specifications are met. For reusable packaging, this necessarily requires that inspection and maintenance operations are performed on a periodic basis. This can range from visual inspection to periodic nondestructive analysis testing. The fabricator of packaging is obligated to manufacture the packaging to the required specifications, and likewise, it is the procurer's obligation to ensure that the correct specifications are requested. Having a quality assurance program involved with fabrication and procurement activities is essential to ensuring compliance in this area.

It is the shipper's responsibility to classify and describe the hazardous material contents in accordance with Parts 172 and 173. The shipper must determine that the packaging or container is an authorized packaging for those contents, including all special requirements, and that the package has been manufactured, assembled, and marked in accordance with the HMR. The shipper may accept the manufacturer's certification, specification, approval, or special permit marking in determining the manufacture and testing compliance of the package.

Based on written instructions by the manufacturer (Section 178.2(c)), the shipper performs all the actions that need to be taken for the packaging to conform to the requirements of Part 178. The

shipper must perform any packaging functions required by Sections 173.24, 173.24a, and 173.24b for which the shipper is responsible, such as filling limits, compatibility between the hazardous material and the container, securing, and cushioning.

## 7.4 SELECTING THE CORRECT PACKAGING

The fundamental key to safe transport of a hazardous material is selection of the right packaging for the material. This area has seen considerable enforcement activity within recent years, and noncompliant shipments can be quite costly. The potential criminal and civil liability of corporate officers and the civil liabilities involved with personal injury lawsuits require that knowledgeable, experienced personnel be involved in the selection process, and due to the complexity, a team effort is generally warranted.

There are often both complementary and conflicting interests that may influence the packaging choice. For example, if shipped for disposal, will the packaging be reused or disposed of with its contents? If destined for storage, is the package design compatible with the receipt and storage requirements at the receiving facility? While these are concerns that must be addressed, the starting point for packaging selection is not with these questions but with the list of the authorized types of packaging in 49 CFR.

The determination as to what packaging is authorized goes back to the earlier discussion of material classification and the choice of proper shipping name. Once the material is properly classed and an appropriate proper shipping name selected, the section of the regulations detailing the authorized packaging is found in Column 8 of the HMT.

Column 8 has three subcolumns. Column 8A lists the sections of the regulations where packaging exceptions are provided (or *None* is indicated if no exceptions are authorized). Packaging exceptions are generally provided when small amounts of material are to be shipped and the material qualifies as a limited quantity. Column 8B lists the available nonbulk packaging, and Column 8C lists bulk packaging. Definitions for bulk and nonbulk packaging are provided in Section 171.8.

***NOTE: The bulk and nonbulk packaging definitions do not apply directly to radioactive material Type A and Type B packaging. Letters of interpretations from DOT state that these packagings have been traditionally treated as nonbulk packagings for hazard communication requirements (marking and labeling), but may also be treated as bulk packaging. This may be clarified by DOT in a future rulemaking.***

Consider a shipper offering gasoline (Class 3, Packing Group II) in a 1-liter (0.3 gallon) metal can that is securely packaged and cushioned within a strong outside container. Is this package eligible for the packaging exception?

Reference to Column 8A of the HMT indicates that Section 173.150 contains a packaging exception. Comparing the package used to the provisions in Section 173.150(b), it is clear that this package of gasoline meets the provisions of Section 173.150(b)(2). This exception is referred to as a *limited quantity*. Therefore, this package of gasoline is eligible to be shipped as a limited quantity and excepted from the specification packaging for all modes of transportation. It is also excepted from labeling for all modes except air, as well as other operational requirements. A limited quantity shipment is simply a package prepared under a limited quantity packaging provision. Notice that there are other packaging exceptions in Section 173.150 for alcoholic beverages and consumer commodities.

If Column 8A indicates *None* (such as for the entry for "Ethyl chloride" in the HMT) or if the package the shipper plans to use does not meet the requirements specified in the exception section to which Column 8A refers, then the material must be packaged in specification packaging. *Specification packaging* means the package meets the construction and testing requirements specified by the DOT or the UN.

Columns 8B and 8C refer the shipper to the section containing the specification packaging requirements. Column 8B contains the references for nonbulk packaging, and Column 8C contains the references for bulk packaging. Thus, if gasoline is packaged in an inside container of 1.2 liters, it does not meet the eligibility requirements of Section 173.150(b)(2) and has to be packaged in specification packaging. Column 8B indicates that the nonbulk specification packaging can be found in Section 173.202. The shipper may choose any appropriate specification packaging listed in that section.

Review Section 173.202 to become acquainted with the different types of packagings. If a shipper wants to package gasoline in metal drums, Section 173.202(b) authorizes the use of several specification combination drums. Paragraph (c) of that section references several single-packaging drums that may be used. Consider the examples in Figure 7-1 for determining the appropriate packaging.

**Determining Appropriate Packaging**

Example 1
You need to ship 2 liters of technical grade 50% nitric acid by highway. This material is listed by technical name in Column 2 of the HMT. The authorized packaging section in Column 8A shows the word *None*, Column 8B shows Section 173.15, and Column 8C identifies Section 173.242 for bulk packaging options. The word *None* in Column 8A means that no packaging exceptions are authorized. Section 173.158(b) specifies the conditions under which this material may be offered in a 1A1 steel drum or a 4H1 plastic outer package with an inner glass bottle. Sections 173.158(e) and (f) list additional packaging options.

Example 2
You need to ship a 0.5-liter solvent mixture of acetone and xylene by highway. Analysis of the mixture determines that the material meets the Class 3, Packing Group II criteria. Since the material is not listed by technical name, chemical group, or functional name in the HMT, assign the proper shipping name of "Flammable liquids, n.o.s." Columns 8A and 8B list Sections 173.150 and 173.202 for the authorized packaging.

**Figure 7-1. Examples of determining appropriate packaging**

## 7.5 PACKAGING STANDARDS

All packaging for hazardous materials must meet certain general packaging requirements. Sections 173.24, 173.24a, and 173.24b prescribe standards for all packages, even specification packages. Often this section is the only standard applicable to a package. For example, the material may need to be packaged in a *strong outer packaging*. What is a strong outer packaging? Section 173.24 provides the only standard for making this judgment. Basically, it provides a performance standard.

Because of the distinct characteristics of each hazard class, there are general packaging requirements that must be considered when preparing a package. For example, many flammable liquids expand when they are heated. For this reason, all containers of flammable liquid must have vacant space, or *outage*, as required by Section 173.24. The hazardous material contents must be compatible with the packaging materials, and there must not be any chemical interactions that would (a) generate gases or vapors or (b) cause heat or pressure increases, since any of these could compromise the packaging integrity.

Section 173.24(b) states that the prepared package must be "designed, constructed, maintained, filled, its contents so limited, and closed so that under conditions normally incident to transportation . . . there will be no identifiable (without the use of instruments) release of hazardous materials . . . the effectiveness of the package will not be substantially reduced . . ."

All packaging closures must close tightly and securely. The shipper must consider the transport conditions, including vibration, temperature, and pressure changes. Inner packaging must remain upright in the outer container. Cushioning material may be needed to hold inner containers fixed within the outer packaging.

Inner containers must also have tightly secured closures. Liquid containers must have leak-tight packaging, such as leak-proof liners or plastic bags. There must also be sufficient absorbent material in the outer packaging to absorb the liquid contents.

Section 173.27 prescribes the general requirements for transport by aircraft that are in addition to the requirements in Section 173.24. The packaging must also meet the performance requirements in Part 178 and the modal requirements in Part 175. The requirements for air shipments are often more restrictive than other modes because of the unique transportation environment associated with air transport. Shippers are required to certify that the hazardous material offered for air transport has been properly prepared and is in compliance with all applicable requirements. (See Sections 173.27(i) and 172.204(c)(3).)

## 7.6 SMALL QUANTITY EXCEPTIONS

Title 49 CFR Part 173.4 provides for packaging exceptions when offering small amounts of certain hazardous materials. Not all hazard classes are covered, and the quantities are limited to 30 mL, 30 g, or, in some instances, 1 g of material. Qualifying materials under this section are excepted from all the requirements of Subchapter C, providing all the requirements in 49 CFR 173.4 are met.

These requirements include provisions to ensure material compatibility and packaging integrity, including a specific package performance standard. While marking, labeling, and shipping papers are not required, the shipper provides certification for the shipment by marking the package with the statement "This package conforms to 49 CFR 173.4. See Section 173.4(a)(10)." The gross mass of the completed package may not exceed 29 kg (64 lb).

Section 173.4(a)(6) requires that the completed package, as demonstrated by prototype testing, be capable of sustaining the following:

- Each of the following free drops made from a height of 1.8 meters (5.9 feet) directly onto a solid, unyielding surface without breakage or leakage from any inner receptacle and without a substantial reduction in the effectiveness of the package:
    - One drop flat on bottom.
    - One drop flat on top.
    - One drop flat on the long side.
    - One drop flat on the short side.
    - One drop on a corner at the junction of three intersecting edges.
- A compressive load as specified in Section 178.606(c) of this subchapter.

A comparable section to Section 173.4 is found in the international air regulations (ICAO 1; 2.5, IATA 2;2.7).

## 7.7 MATERIALS OF TRADE EXCEPTIONS

Another section of the regulations that provides packaging exceptions for small amounts of material used as part of a business is the materials of trade section in 49 CFR 173.6. This exception is restricted to highway transport only. *Materials of trade* are hazardous materials that are carried by motor vehicle for at least one of the following purposes:

- To protect the health and safety of the motor vehicle operator or passengers (e.g., insect repellent, self-contained breathing apparatus, fire extinguishers).
- To support the operation or maintenance of a motor vehicle or auxiliary equipment (e.g., engine starting fluid, spare battery, gasoline).
- To directly support a principal business that is not transportation (e.g., lawn care, pest control, plumbing, welding, painting) when carried by private motor carrier.

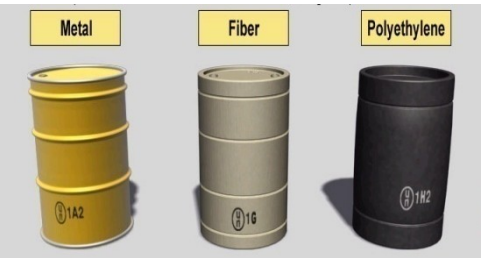
Only the specific hazard classes listed in Section 173.6 are eligible for this exception, and while shipping papers are not required, there are specific packaging and marking requirements. The packaging must be:

- Leak-tight for liquids and gases.
- Sift-proof for solids.
- Securely closed.
- Secured against movement.
- Protected against damage during transport.

Each package must be either the manufacturer's original packaging or a packaging of equal or greater strength and integrity. The packages must be marked with a common name or proper shipping name and RQ, if appropriate. The operators of the motor vehicle must be knowledgeable of the hazards associated with the material, must be informed if there is an RQ of the material, and must be aware of the requirements for this material under Section 173.6.

***NOTE: Material identified as Class 7 (Radioactive) is not authorized as a material of trade.***

## 7.8 LAB PACKS




The lab pack provisions are found in Section 173.12(b). This section of the regulations was originally a DOT packaging exemption for shipping specified waste shipments. Due to the extensive use of this exemption, the DOT incorporated the exemption into the regulations. Only the listed hazard classes in Section 173.12(b) may be shipped as lab packs, excluding the prohibited materials listed in Section 173.12(b)(3). The shipments must be for disposal or recovery and transported only by highway, rail, or cargo vessel.

***NOTE: Material classed as Class 7 cannot be shipped as a lab pack.***

The section also provides regulatory relief for specified hazard communication and material segregation requirements. Lab packs consolidate small containers of chemicals having the same hazard class within a specification drum (UN1A2 metal drum, UN1G fiber drum, or UN1H2 plastic drum). The drums must meet the Packing Group III performance criteria for liquids or solids.

The inner glass containers may not exceed 4 liters (1 gallon), and the inner metal or plastic containers may not exceed 20 liters (5.3 gallons). The gross weight of the completed package may not exceed 205 kg (453 lb). An inner packaging with liquids must be surrounded by a chemically compatible, absorbent material in sufficient quantity to absorb the total liquid contents.

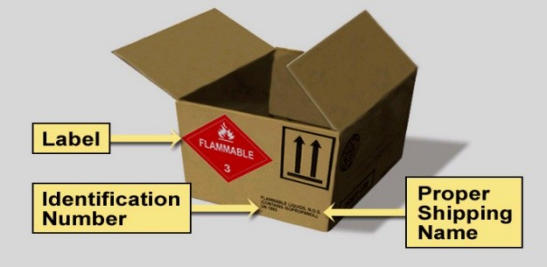
## 7.9 SALVAGE DRUMS

Section 173.3(c) provides for damaged, defective, or leaking hazardous material packages to be placed into metal or plastic salvage drums and shipped for repackaging or disposal. Salvage drums must comply with the provisions in Section 173.3(c)(1)–(7). The drums may be metal or plastic removable-head drums and must be compatible with the hazardous material.

Generally, salvage drums must be UN1A2, UN1B2, UN1N2, or UN1H2 and meet at least the Packing Group III performance criteria. The drum must have sufficient cushioning and absorbent material to prevent excessive shifting of the damaged inner package and eliminate any free liquid at the time the drum is closed. Each salvage drum must be marked with:

- The proper shipping name.
- The name and address of the consignee.
- The words *Salvage* or *Salvage Drum*.

## 7.10 OVERPACKS




An *overpack* is defined in Section 171.8 as an enclosure that is used by a single consignor to provide protection or convenience in handling a package or to consolidate two or more packages. It does not include the:

- Transport vehicle.
- Freight container.
- Aircraft unit load device.

***NOTE: This definition does not apply to radioactive material overpacks, which are described in Part 178, Subpart K.***

Overpacks must be marked with the word Overpack unless the specification markings on the inside of the package are visible. Specific requirements for overpacks are found in Section 173.25.

## 7.11 EMPTY PACKAGING

Generally, an empty package containing residue must be offered for transport in the same manner as when it contained a greater quantity. Certain regulatory exceptions are provided for empty packaging in Section 173.29. Placarding exceptions are provided in Sections 173.29(c) and (h). Section 172.203(e) provides for the phrase *Residue: Last Contained **** to be entered in association with the basic description of the hazardous material last contained in the packaging.

## 7.12 SPECIAL PERMITS (PREVIOUSLY KNOWN AS EXEMPTIONS)

Periodically, shippers may find that the material and/or the available packaging simply do not fit within the requirements of 49 CFR. In such cases, shippers may petition the DOT for a special permit authorizing specified deviations from the regulations. This process is outlined in 49 CFR 107.105.

Section 107 of the Hazardous Materials Transportation Act (49 United States Code 1806) gives the Secretary of the DOT the authority to grant exemptions from the provisions of the Act and the regulations enacted under the authority of the Act, provided certain conditions are met. In 2005, the DOT decided to refer to exemptions as *special permits*. Part 107 of 49 CFR starting at Section 107.101 (49 CFR 107.101) sets forth the procedure to apply for a special permit, the administrative procedure to process the application, and other items of concern to those persons seeking relief through the special permit process.

The special permit process does not allow a shipper to simply disregard the regulations, but it allows for an alternative method of transport that provides an equivalent level of safety as that afforded by compliance with the regulations. The petitioner, therefore, must state the specific requirement in 49 CFR from which relief is requested and then justify how the proposed method of packaging/ transport compensates to provide equivalent safety.

Special permits generally expire after 2 years, but they may be renewed if there is a continuing need. Renewals generally expire after 4 years. The renewal process is found in 49 CFR 107.109. Only persons listed as parties to the special permit may use it. A special permit issued to DOE or one its contractors may not be used by other contractors or subcontractors unless they also become a party to the special permit. The application process for party status is detailed in 49 CFR 107.107.

When using a special permit, all the provisions stated in the special permit must be met. In addition, all other applicable requirements in 49 CFR must be followed. For example, a shipper is still subject to all the communication requirements if the special permit only grants packaging relief.

Generally, packages offered under a special permit are required to be marked with the special permit number. In some cases, a copy of the special permit is required to be in the possession of the carrier during transport. A list of current DOT special permits can be found at this website: http://hazmat.dot.gov/sp_app/approvals/exsys.htm.

Although there are certain similarities between special permits and exceptions, they are two different terms. Both a special permit and an exception provide relief from the HMR as long as certain conditions are met. Exceptions are specifically listed in 49 CFR and apply in accordance with the stated conditions. Special permits are not specifically set forth in 49 CFR, since they apply only to the specific person or class of persons to whom they are issued or the parties to the special permits. Special permits are issued by the DOT only in response to a written application submitted in accordance with Part 107, Subpart B.

Any person subject to the regulations (shipper, carrier, or container manufacturer) may apply for special permits (Section 107.107). Generally, only the holder of a special permit or a party to the permit may operate under its authority. Section 173.22a provides that if the special permit authorizes use of a packaging by "any person" or a "class of persons" other than or in addition to the holder of the special permit, then the packaging may be used by "any person" or a member of the

class specified if they otherwise meet the requirements of Section 173.22a(b). For example, a "class of persons" could be any shipper or customers of "X" company.

If a renewal application is submitted at least 60 days prior to the expiration of the current special permit, the special permit will remain in effect until a final determination is made on the renewal application, regardless of the fact that the special permit has expired.

All special permits are issued in the same format. The first paragraph will vary depending on whether the special permit is granted to a shipper, carrier, or manufacturer. The special provisions in paragraph 8 will vary depending on the circumstances involved. A copy of the special permit is not always required to be carried. However, this condition can only be determined by reading the actual special permit. It is important to note that a special permit grants relief only to those regulations specifically stated under "Regulation(s) Affected," which is usually paragraph 5 of the special permit.

DOE contractors must follow the requirements in DOE Order 460.1B for requesting special permits. The DOE Order requires that all requests be processed from the field to Headquarters Office of Environmental Management for processing to the DOT. Special permits will generally be held by DOE, with the contractors holding status as a party to the permit.

## 7.13 REVIEW QUESTION SET 8

1. What column(s) in the HMT in 49 CFR specify the packaging sections?

   Subcolumns 8A, 8B, and 8C

2. What column(s) in the IATA "List of Dangerous Goods" specify the packaging sections?

   Columns G, I, and K

3. What sections of 49 CFR contain the requirements for:

   - General requirements for the types of packaging? 173.24, 24a, 24b
   - Empty packages? 173.29
   - Overpacks? 173.25
   - Salvage drums? 173.3(c)

4. What section of 49 CFR contains the assignment of packing groups for Class 3 material?

   173.121

5. Assign packing groups for the following Class 8 materials:

   - A material with a corrosion rate on steel or aluminum surfaces exceeding 6.25 mm a year at a test temperature of 55°C, but it does not degrade intact skin tissue

     Packing Group II 173.137(c)(2)

   - A substance that causes full thickness destruction of skin tissue at the site of contact when tested on intact skin for a period of not more than 3 minutes

     Packing Group I

6. Provide the UN ID code for the following packaging types:

   - Aluminum drums: 1B
   - Plywood drums: 1D
   - Fiber drums: 1G 178.502
   - Plastic drums: 1H
   - Fiberboard boxes: 4G

7. What are the performance drop test heights for packages with the following performance levels that will contain solid hazardous materials:

   - Packing Group I? 1.8 meters
   - Packing Group II? 1.2 meters 178.603(e)(1)
   - Packing Group III? 0.8 meter

8. Which of the following classes of materials can be shipped as a lab pack?

   - **Class 8 173.12(b)**
   - **Class 3 173.12(b)**
   - Class 7 **Not Listed**
   - Class 6.1, Packing Group I **Prohibited in 173.12(b)(2)(ii)**
   - Class 4.2, Packing Group I **Prohibited in 173.12(b)(2)(ii)**

9. What is the maximum amount of waste that can be placed in an inside glass packaging in a lab pack?

   **4 liters 173.12(b)(2)(ii)**

10. Can lab packs be shipped by air under the IATA regulations?

    **No. 173.12(b)**

11. Must the technical names of the individual chemicals packed in a lab pack be shown as a package marking and on shipping papers?

    **No. 173.12(d)**

12. By what mode of transport and for what purposes may a material be transported as a material of trade?

    **171.8 Definition**

    **By highway; protect health and safety of driver/passenger; supporting operation/ maintenance of vehicle; by private motor carrier in direct support of business other than transportation**

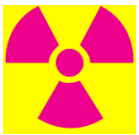
13. What are the hazard communication requirements for a material of trade?

    **173.6(c)**

14. What are the packaging testing requirements for a small quantity shipment?

    **173.4(a)(6)**

## 7.14 RADIOACTIVE MATERIAL PACKAGING



Safety in transporting radioactive material primarily depends on use of the proper packaging for the type, quantity, and form of the radioactive material. Packaging designs for radioactive materials are performance-oriented designs, with the packaging integrity being dictated by the hazards of the radioactive content.

There are five categories of radioactive material packaging:

- Excepted packaging.
- IP-1, IP-2, and IP-3 (for LSA material and SCO only).
- Type A packaging.
- Type B packaging.
- Type C packaging (not recognized for domestic shipments).

Radioactive material packages are subject to the general hazardous material packaging requirements contained in 49 CFR 173.24 and 173.24a and to the general design requirements in Section 173.410 for radioactive material packaging. The responsibility for establishing packaging standards for radioactive material is split between the NRC and DOT. The DOT establishes the packaging standards for low-risk material, and the NRC has responsibility for the packaging standards for high-risk material.

The packaging pyramid in Figure 7-2 shows the relationship between the different packaging types and how the requirements increase as you progress from excepted packaging up through Type B packaging. It also shows the relationship between the NRC and DOT packaging standards.

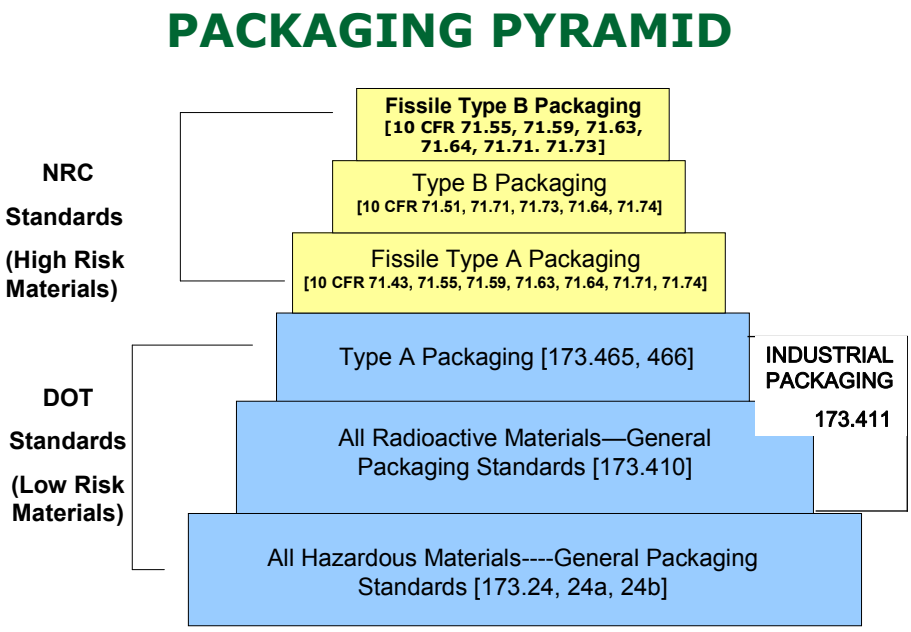



**Figure 7-2. Packaging pyramid**

General Packaging Requirements

Packaging for hazardous materials is subject to the applicable general requirements in 49 CFR 173, Subparts A and B, and Section 173.410, "General Design Requirements." Shippers and package designers should review Section 173.24, “General design requirements for packagings and packages,” and Section 173.24a, “Additional Design Requirements for non-bulk packagings and packages,” to determine which requirements apply. The bulk and nonbulk packaging definitions do not apply directly to radioactive material packaging, and the DOT has traditionally treated Type A and Type B packaging as nonbulk packaging.

An example of a requirement that is applicable to all packages is the performance capability requirement for vibration in Sections 173.24a(a)(5) and 173.410(f). Packages do not require vibration testing in a laboratory. Demonstrating compliance by methods other than testing is allowed in Section 173.461(a)(4). The DOT has provided letters of interpretation that the vibration requirement in Section 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.

When deciding on the material for lifting attachments, consideration should be given to material that will not yield under the range of loads expected in normal handling. The effects of wear should also be considered. Attachment points are critical for packages that will be lifted many times over the course of their life. Fatigue behavior should be taken into account, and the design should allow for detecting cracks by nondestructive means.

Where practical, the package design should be simple and allow for easy decontamination. Protruding features on the packaging exterior are vulnerable to impacts during handling and transport. Such impacts can cause high stresses in the packaging structure and compromise containment.

Exterior surfaces with a smooth finish and low porosity are less susceptible to absorbing contamination and subsequent “weeping.” Collection and retention of water (on lids) can result in rusting and also contribute to contamination leaching. In addition, water dripping from packages can be misinterpreted as leakage from a package.

The packaging components (including those associated with containment, lifting attachments, and load securement) can loosen as a result of acceleration, vibration, and vibration resonance. The packaging design should ensure that the fasteners remain secure during routine conditions of transport.

Packaging material compatibility should take into account the effects of corrosion, embrittlement, gas generation, thermal expansion, radiolysis, etc., and should consider the compatibility of the packaging material and the contents. When designing packaging that will be transported by air, additional consideration must be given to changes in temperature and pressure.

## 7.15 EXCEPTED PACKAGING

In addition to the general packaging requirements for all hazardous material packaging (Section 173.24), excepted packaging must meet the general requirements for radioactive material packaging in Section 173.410. Excepted packaging is authorized when smaller quantities or lower-hazard radioactive material is being shipped.

Excepted packaging is expected to retain its contents (no releases) under routine (incident free) transport. The conditions relating to routine transport include climatic changes such as temperature and pressure and inertial forces due to:

- Uneven road or track.
- Vibration.
- Linear accelerations and decelerations.
- Directional changes.
- Road skids (no impact).
- Heavy seas.
- Air turbulence.

Excepted packages are not required to be tested or designed to survive any transportation accidents. It is assumed that all the contents could potentially be released under accident conditions. Therefore, the total activity and maximum allowable dose rates associated with these packages are significantly lower than those allowed for Type A and Type B packages.

## 7.16 INDUSTRIAL PACKAGING

Material with sufficiently limited specific activity (LSA material) and certain SCO are authorized to be shipped in IP-1, IP-2, or IP-3. These are the only materials authorized for this packaging. IP integrity is graded in relation to the hazard posed by its contents. Each IP-1 must meet the general packaging requirements of Section 173.410 and is, therefore, equivalent to excepted packaging.

Each IP-2 must meet the general design requirements of an IP-1. In addition, when subjected to the free drop and stacking (compressive load) tests specified in Sections 173.465(c) and (d) or evaluated against these tests by any of the authorized methods of Section 173.461(a), each IP-2 must prevent:

- Loss or dispersal of the radioactive contents.
- Any significant increase in the radiation levels recorded or calculated at the external surfaces for the condition before the test.

Each IP-3 must meet the requirements of an IP-1 and IP-2 and must also meet the requirements specified in Section 173.412(a)–(j). An IP-3 is, therefore, identical to the Type A packaging authorized for solid Type A quantities of radioactive material.

Freight containers that meet the IP-2 and IP-3 requirements and are built to the ISO 1496-1 specifications may be used as IP-2 and IP-3 packaging. See Section 173.411(b)(6) for the specific requirements.

Shippers of IP-2 and IP-3 packages/ containers must maintain the packaging documentation on file for 1 year after shipment. The documentation must show by test results or analysis that the packaging met the IP-2 or IP-3 criteria.

**Standards and Tests for Industrial Packaging**

- IP-1 meets the general design requirements in Section 173.410.
- IP-2 meets the Type A packaging drop and stacking tests.
- IP-3 meets the Type A tests for solids.

## 7.17 TYPE A PACKAGING

Type A packaging must meet Section 173.410 and the testing requirements in Section 173.465. Authorized Type A packages are listed in Section 173.415. Packaging for Type A quantities of radioactive material may be (a) DOT specification packaging, (b) Type A packaging designed and tested commercially or by DOE, or (c) Type A or Type B packaging certified by DOE or the NRC. Foreign-made Type A packaging may also be used for both domestic transport and export.

Many Type A packages used by DOE are designed, tested, and self-certified as DOT 7A. Each user of DOT 7A packaging must maintain complete documentation of tests and other data that demonstrates that the packaging met all of the Type A requirements.

The specifications for DOT 7A Type A packaging are presented in 49 CFR 178.350. These specifications require that each packaging meets all applicable requirements of 49 CFR 173, Subpart B, and be designed and constructed so that the packaging meets the requirements of 49 CFR 173, Subpart I, Sections 173.403, 173.410, 173.412, 173.415, and 173.465. Each packaging built to DOT 7A Type A must be marked on the outside with the words *USA DOT 7A Type A* and also be in accordance with the marking requirements in Section 178.3.

To satisfy the documentation requirements of 49 CFR 173.415(a), some form of documentation should be available that shows consideration of each requirement. It is recommended that the documentation identify the requirement and follow with a statement that the requirement has been met and how it was met. The statement can contain references to supporting documentation, such as engineering evaluations. DOE has a testing program for Type A packaging and maintains a database of the approved packaging designs in the *Test and Evaluation Document for DOT 7A Type A Packaging* that can be accessed at http://rampac.energy.gov/.

The specific packaging data contained in this DOE evaluation document will serve to meet the requirements of 49 CFR 173.415(a) for "documentation of tests" when the packaging is used as prescribed therein. However, shippers are cautioned that additional documentation will be needed to fulfill all of the requirements for a particular shipment; most importantly, that the contents to be shipped have been evaluated for compatibility with the packaging and that their characteristics have been bounded by the simulated contents used in qualification testing.

DOE contractors may use any of the packagings identified in the testing document, as long as the packaging is used in accordance with its tested parameters. Type A packages purchased from commercial vendors do not require retesting by DOE, but (a) the vendor's quality assurance program should be equivalent to DOE's program and (b) the shipper must maintain the packaging testing documentation.

### Type A Packaging Tests

Type A packaging must comply with the applicable general packaging requirements of Sections 173.24, 173.24a, and 173.410 and the additional requirements of Sections 173.412 and 173.415. The package must prevent the loss or dispersal of the radioactive contents and maintain its radiation shielding properties during normal conditions of transport, which include rough-handling conditions. These normal transport conditions include:

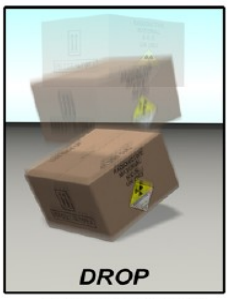
- Changing climatic conditions: humidity, temperature, pressure, solar heating, and rain.
- Dynamic and static mechanical effects: limited shock, repeated bumping, and/or vibration.
- Compressive forces due to stacking and load movement.

The tests and their sequence are specified in 49 CFR 173.465 as follows:

1. Water Spray Test, which simulates the package having been left in the rain for a period of 1 hr.
2. Drop Test of 1.2 meters (4 feet) onto a hard surface in the most damaging orientation, which simulates falling off a vehicle or loading platform. There are different drop heights based on the package mass.
3. Penetration Test with a 6-kg (13-lb) steel rod being dropped from 1 meter (3.3 feet) onto the damp package, which simulates a loose object hitting the package.
4. Stacking (compression) Test equal to a force of at least 5 times the weight of the package, which simulates the damp package being at the bottom of a stack of packages.

The water spray test is primarily intended for packaging comprised of material that absorbs water or is softened by water or material that is bonded by water-soluble glue. Packaging with outer surfaces entirely of metal may be shown to pass the test by reasoned argument, provided that it does not retain water.

Water spray for 1 hour to simulate rainfall of 2 inches per hour.



Free-drop test onto a flat, hard surface. This test is conducted only on packages weighing 11,000 pounds or less.

The free drop test simulates the type of shock that a package would experience if it were to fall off a vehicle or be dropped during loading or unloading. In most cases, the package would be able to continue in the transport system after being dropped. Since heavier packages are likely to be exposed to large drop heights during normal handling, the free drop distance is graded according to the package mass. Lighter packages require additional drops to simulate repeated impacts during handling.

The compression test is designed to simulate the effect of loads pressing on a package over a prolonged period of time to ensure that the effectiveness of the shielding and containment systems will not be impaired, and in the case of fissile material contents, that the compression will not adversely affect the configuration.

Compression test of at least 5 times the weight of the package. This test is conducted for at least 24 hours.

Penetration test by dropping a 13-pound, 1.25-inch diameter bar vertically onto the package from a height of 3.3 feet.

The penetration test is intended to ensure that the contents will not escape from the containment boundary and that the shielding or confinement boundary will not be damaged if a slender object should fall or strike the package and penetrate the outer layers of the packaging.

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 the material spreading if the package containment system fails. The more stringent requirements relate to containment and the height in the drop tests, and these are provided in Sections 173.412(k) and 173.466.

Normal conditions of transport include minor mishaps, and the Type A tests are designed to address these occurrences. For example, the drop test is intended to simulate the damage that could occur as a result of falling from the vehicle or being dropped during handling. In most cases, the packages will be relatively undamaged and able to remain in the transport system.

Type A packages have historically performed very well in many accident conditions. Current national and international data shows that there have been approximately two dozen accidents involving

consignments of multiple Type A packages. There were releases of radioactive contents in only two of these events, and the releases were on the order of $10^{-4}$ $A_2$ quantity.

### DOT 7A Type A Packaging

Essentially, the only DOT-approved Type A packaging in the DOT regulations is the DOT 7A packaging, which is based totally on performance test conditions rather than on hardware or design requirements. This provides the packaging designer with the maximum latitude in the using engineering creativity to produce optimally useful, economic designs.

Using any of the methods authorized in Section 173.461, each shipper of a DOT 7A package must determine if the DOT 7A design meets the performance requirements in Sections 173.412 and 173.465 and must document and maintain this evaluation, or self-certification, on file for at least 1 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 (content weight, material form, closure, etc.), the performance capability of the modified package must be reevaluated with respect to the requirements before the Type A designation may be assigned.

The DOT 7A designs do not require the approval of either the DOT or the NRC for domestic shipments or for international transportation of nonfissile radioactive material. Imported packaging that is marked with *Type A* and the country of origin and meets the IAEA regulations is 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 packaging designer.

### NRC-Approved Packaging for Type A Quantity Shipments

In authorizing use of NRC-approved packages for transport of Type A quantities of radioactive material, the DOT regulations specify in 49 CFR 173.415 that certain conditions must be met. One condition is that the shipment of the package be made in compliance with the terms of the NRC Certificate of Compliance. (See 49 CFR 173.471.)

For example, a radiographic source changer packaging authorized for a Type B quantity of a specific radionuclide in special form is also authorized for a Type A quantity of the same specific radionuclide in special form, provided all the terms and conditions of the certificate are met. Note that the NRC approvals include the type and form of material, the maximum quantity of material per package, and the operating instructions and maintenance procedures for the package.

Alternately, an NRC-approved packaging may be shipped under the provisions of 49 CFR 173.415(a) as a DOT 7A package. In this instance, the shipper (if requested) must provide the DOT with complete documentation of the tests and an engineering evaluation or comparative data showing that the construction methods, packaging design, and materials of construction comply with DOT 7A.

Thus, a radiographic source changer packaging approved by the NRC for shipment of a specific radionuclide in special form could be used to ship a Type A quantity of a different nuclide, provided that the package is reevaluated under the provisions of 49 CFR 173.415(a). When an NRC-approved package is used as a DOT 7A package, the NRC packaging identification marking should be covered and the DOT 7A Type A markings should be affixed.

### Type A Fissile Packaging

The NRC approves package designs for shipment of all fissile Type A quantities of radioactive material. Under 10 CFR 71.55, Type A fissile packaging must meet the same requirements as nonfissile Type A packaging. In addition, the contents must be shown to remain subcritical when the package is subjected to the hypothetical accident tests in 10 CFR 71.73. There are additional testing requirements when the packaging will be transported by air and if the content is Pu.

See 10 CFR 71.55, 71.59, 71.63, and 71.64. Authorized Type A fissile packages include packaging where an AF certificate has been issued by the NRC, DOE, or IAEA.

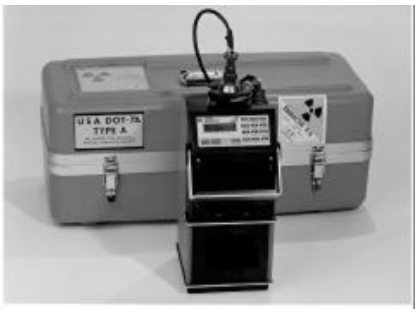
As an alternative to an AF certificate packaging, fissile material may be shipped in the DOT 7A package. Use of the DOT 7A package is restricted to the mass limits found in 10 CFR 71.22. An additional 1-foot drop test is required under Section 173.465(c)(2).

***NOTE: If a DOT 7A packaging is used for fissile material, a Certificate of Competent Authority Approval must be issued before it can be exported. (See Section 173.472.)***

### Typical Type A Packaging Configurations

The following are descriptions of several typical nonfissile Type A packaging configurations.

*Moisture Density Gauge and Carrying Case*
Contents: Special form, AmBe source, 2 GBq (50 mCi) and $^{137}Cs$, 0.4 GBq (10 mCi)




*Research/Medical Isotope Shipping Container*
Contents: Medical radioisotopes in solid or liquid form

*Steel Drum (55 gallon)*
Contents: Various radionuclides, 0.1 GBq to 40 TBq (3 mCi to 1000 Ci)

*Carton for Medical/Research Radionuclide in Liquid Form*
The picture shows the carton, foam spacer, shielding, secondary container, absorbent, and primary container
Contents: Various radionuclides, 10 MBq to 40 TBq (0.3 mCi to 1000 Ci)

## 7.18 TYPE B PACKAGING

In addition to the requirements for Type A packaging, the NRC-, DOE-, or IAEA-approved packaging must meet the hypothetical accident condition tests specified in 10 CFR 71. The required tests include free drop, crush, puncture, thermal, and immersion tests. These tests are intended to account for a wide range of accidents possible by all modes of transport. The tests expose the package to severe dynamic forces. The package should survive the most severe transport accident conditions without loss of containment or increase in the external radiation level to an extent that would endanger the public or those involved in rescue or cleanup operations. It should be safely recoverable but not necessarily capable of being reused.

The DOT has also authorized certain specification packaging for Type B quantity material (i.e., the 20PF and 21PF series of $UF_6$ packaging).

***NOTE: Older packaging designs designated as B( ), and the DOT Specification 6L, 6M, 20WC, and 21WC packaging were not authorized after October 1, 2008. The open parentheses designation indicated that the package design and approval were in accordance with the 1967 edition of the IAEA regulations. Some of these packagings may still be in use for storage and onsite transfers at DOE sites.***

Currently, certified authorized Type B packagings are designated as Type B(U), Type B(M), and those with -85 or -96 at the end of the designation. An overview is provided below.

- Type B(U) and B(M) packaging designs were approved to the 1973 regulations and had NRC and DOE approval prior to April 1, 1996.
- Package designs with -85 were approved after April 1, 1996, and meet the 1985 IAEA regulations.
- Package designs with -96 meet the 1996 IAEA regulations.
- Use of package designs without the -85 or -96 designation is restricted by both the NRC and DOE in terms of export, and this also applies to any design modifications.
- The (U) designation indicates a design requiring only unilateral approval—approval by the country of origin only. The receiving country does not need to review these designs, but in general, they will revalidate the certification.
- The (M) indicates a design requiring multilateral approval (i.e., approval by all countries into or through which the package is transported).
- A Type B(U) and a Type B(M) packaging are identical, except that a Type B(M) packaging design has a maximum normal operating pressure greater than 700 kilopascals or a pressure-relief device that allows the release of radioactive material to the environment under the hypothetical accident condition tests.
- Certificate Type B packaging that is authorized for fissile material has an "F" in the identification (e.g., USA/9126/B(U)F-85).

Under the international regulations, Type B packages transported by air are restricted to 3000 $A_2$. For special form material, the restriction is to 3000 $A_1$ or 100,000 $A_2$.

### Authorized Type B Packaging – Domestic Use

The vast majority of authorized Type B packagings are NRC-certified designs. Each design is approved under an NRC Certificate of Compliance and General License issued pursuant to 10 CFR 71.17. The DOT authorization for use of NRC-approved Type B packagings is provided in Section 173.416(a), and the standard requirements applicable to their use are contained in Section in 173.471. In addition, numerous Type B packagings currently being used are those approved by

DOE pursuant to the authority provided by the DOT in Section 173.7(d). Some of these DOE-certified packagings are also certified by the NRC.

### Foreign-Made Type B Packaging

Type B packaging of foreign origin that meets the applicable requirements of the IAEA and for which the foreign Competent Authority Certificate has been revalidated by the DOT pursuant to Section 173.473 (see also 10 CFR 71.21) is authorized only for export shipments from, import shipments into, and shipments traveling through the United States. For purely domestic shipments of such packages, the NRC's certification of the packaging must be obtained.

### Type B Packaging Tests

Type B packaging must meet the general packaging and performance standards for Type A packages. In addition, they must have the ability to survive serious accident damage tests (hypothetical accident conditions). After testing, there can 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 that the packaging designer must use to assess the Type B packaging design against the established hypothetical accident conditions are prescribed in 10 CFR 71.73 and include the following sequential tests:

- Free fall of the test package from 9 meters (30 feet) onto an unyielding surface.
- 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 lb) steel plate mass from 9 meters (30 feet) onto the test package.
- A puncture test as a free drop of the test package from a height of 1 meter (40 inches) onto a 15-cm-diameter (6 inch) vertical steel peg.
- Exposure to a thermal environment of 800°C (1475°F) for 30 minutes.
- Water immersion of the test package under at least 15 meters (50 feet) depth.
- 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 meter (3 feet).

***NOTE: The NRC Regulatory Guides in Division 7, Transportation, are reference resources for the engineering tests listed above (i.e., Regulatory Guides 7.3, 7.4, 7.6, 7.8, 7.11, and 7.12).***

The purpose of the drop tests and the subsequent thermal test is to subject the package to damage equivalent to that which would occur if the package was involved in a severe accident. The order and type of the tests are considered to correspond to the order of environmental threats to packaging in real transportation accidents. The test sequence also ensures mechanical damage to the package prior to the thermal test, thereby ensuring the package is vulnerable to the maximum thermal damage. For fissile material packages, criticality analyses must be performed that consider the damage resulting from the drop tests and the thermal test.

The tests for Type B(U) and B(M) certificate packages are summarized below. Section 173.413 references 10 CFR 71 (i.e., 10 CFR 71.71, "Normal Conditions of Transport," and 10 CFR 71.73, "Hypothetical Accident Conditions").

- Free Drop – 9 meters (30 feet)

  The speed on impact is 30 miles per hour, which is meant to simulate damage to a package from:

  - Being struck by a train at 60 miles per hour.
  - Falling from a 30-foot bridge onto solid rock or falling from a higher bridge onto a roadway or rail.
  - Running into a bridge support or rock slope at 45 miles per hour.

- Crush

  The crush test is meant to simulate damage to a package when it is under a vehicle during a pileup or when the package is pinned between two vehicles during a collision.

- Puncture

  The speed on impact is 10 miles per hour, which is meant to simulate damage to a package from:

  - Being speared by the frame rail from a truck.
  - Being skewered by a railroad track.

- Thermal

  The thermal test is meant to simulate damage to a package when it is in an accident with a gas tanker truck or with 5000 gallons of fuel, fully engulfed, and with no protection to the package from the vehicle.

- Immersion

  The immersion test is meant to simulate damage to a package when it is submerged at sea or in a river.

Figure 7-3 shows an "unyielding surface" at Sandia National Laboratories that is used for drop tests of radioactive material packages.

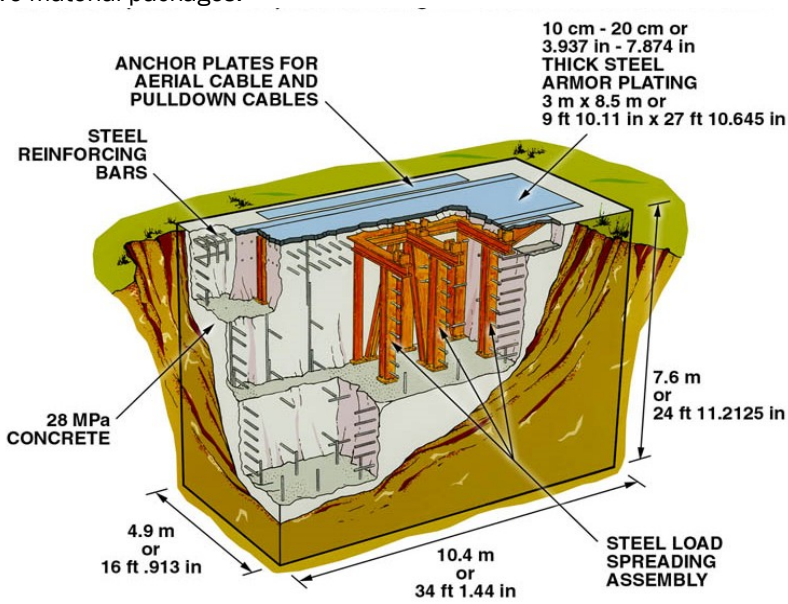



**Figure 7-3. Unyielding surface at Sandia National Laboratories used for drop tests**

### Fissile Material Packaging and Packaging Authorized for Plutonium

Fissile material packaging may be either Type A or Type B, as described above. There are additional criteria related to criticality safety that must be met by all fissile material packaging designs. NRC- or DOE-certified packaging designs authorized for fissile contents must have been evaluated under the requirements in 10 CFR 71.55 and 71.59. These criteria are summarized as follows:

- AF packaging must meet the Type A packaging test requirements and remain subcritical under the tests in 10 CFR 71.71 and 71.73.
- BF packaging must meet the Type B packaging test requirements and remain subcritical under the tests in 10 CFR 71.71 and 71.73.
- All fissile packaging must meet the general requirements for fissile packages in 10 CFR 71.55.
- For air transport, 10 CFR 71.55(f) has additional requirements for subcriticality under the Type C package tests.
- The CSI must be assigned in accordance with 10 CFR 71.59.
- Pu shipments are subject to 10 CFR 71.63, 71.64, 71.74 and 71.88.

### Type C Packaging

Type C packaging was introduced in the 1996 IAEA regulations and is similar to Type B packaging, but it must also be capable of withstanding the severe accident conditions associated with air transport. Basically, this category of packaging is for highway route-controlled quantities transported by air. These packages require unilateral approval unless they contain fissile material, in which case multilateral approval is required.

An exception to the Type C packaging requirement is for low dispersible material, which must meet certain testing requirements. (See the definition and requirements in the international regulations.) These materials may be shipped in Type B packaging with multilateral approval of both the packaging design and the low dispersible material.

*NOTE: The DOT and the NRC have chosen not to adopt Type C packaging at this time.*

### Fissile Material Packaging by Air

In addition to the accident condition tests for Type B packaging, fissile material packaging designs for air transport must remain subcritical after being subjected to enhanced puncture, thermal, and drop tests in addition to the 10 CFR 71.73 free drop and crush tests. These additional requirements are stated in Section 71.55(f). Title 10 CFR Parts 71.74 and 71.88 address the additional requirements for Pu shipments by air.

### Competent Authority Approvals for Import/Export of Specific Packaging Designs

Certain packaging designs require competent authority approval before they can be used for importing or exporting. The Competent Authority will issue a Competent Authority Certificate in accordance with 49 CFR 173.471–473. Shipments that require multilateral competent authority approval are:

- All fissile packages.
- Type B(M) packages and -85 packages.
- Fissile shipments where the sum of the CSIs is greater than 50.
- Type C packages (highway route-controlled quantity shipments by air).

## 7.19 TYPICAL TYPE B PACKAGES

The following are typical Type B packages. Type B packages cover a wide range of physical sizes, from small radiographic devices to large waste casks and spent nuclear fuel casks.

*Transuranic Waste Cask (RH-TRU 72-B)*
Weight: 85,000 lb
Contents: Remote-handled transuranic waste

*TRUPACT-II*
Dimensions: 1.9 meters outer dimension by 1.9 meters
Weight: 8740 kg
Contents: Nonfissile and fissile transuranic radionuclides dispersed in processed solid waste inside drums or other containers. The activity and fissile content are restricted for both the inner container and total package, which is typically in the GBq to TBq range.

## 7.20 QUALITY CONTROL AND QUALITY ASSURANCE REQUIREMENTS

The DOT requirements for quality control are located in 49 CFR 173.474, "Quality control for construction of packaging," and 173.475, "Quality control requirements prior to each shipment of radioactive material." The 10 CFR 71 requirements contain essentially identical paragraphs as Sections 71.85 and 71.87.

The DOT quality control requirement to survey packages of radioactive material prior to shipment is found in Section 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: The requirement to ensure compliance with the radiation and contamination limits of Sections 173.441 and 173.443 does not require that surveys or direct measurement be made. Both sections give shippers latitude in their methods of ensuring compliance with the radiation and contamination limits. The DOT letters of interpretation have indicated that procedures other than measurements, such as quality assurance and quality control, are acceptable means of ensuring compliance. However, if a compliance inspection during transportation determines that the radiation or contamination levels exceed the limit, the shipper is subject to a citation.***

In addition to the above-mentioned generic quality control requirements in 10 CFR 71.85 and 71.87, Subpart H contains specific quality assurance requirements associated with use of NRC-certified Type B and fissile material packages used under the general licenses of Sections 71.17, 71.20, and 71.21. 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 its quality assurance program associated with use of the package approved by the NRC as meeting the applicable requirements of Subpart H.

DOE, as a user of NRC-certified packages, imposes quality control requirements on its contractors through DOE Order 460.1B. Contractors using fissile or Type B packaging must have DOE-approved quality assurance programs that meet the requirements in 10 CFR 71, Subpart H. In addition, if DOE is registered with the NRC as a user of an NRC-certified packaging, DOE contractors may use that packaging without having to register with the NRC.

**Use of NRC Certificate Packaging**

- Authorized under Section 173.417(a)(1)(ii)
- DOE contractor must have an approved Quality Assurance Plan meeting 10 CFR 71, Subpart H (approved by DOE, per DOE Order 460.1B)
- Section 173.471 requires the user of an NRC-certified package to be registered with the NRC prior to shipment (DOE contractors do not have to register if DOE is registered.)
- Contractor must comply with all provisions of the certificate, including referenced sections in the Safety Analysis Report for Packaging addressing operating procedures and maintenance requirements

## 7.21 RESTRICTIONS ON PACKAGING USED FOR DOMESTIC AND INTERNATIONAL SHIPMENTS

### Use of Older Packaging Designs [B(U), B(M), -85]

The timeline in the previous section shows that the design requirements for Type B packaging have changed significantly over the years. DOE still uses packagings that were designed to the 1967 IAEA standards. When evaluating Type B packaging either for shipment or as part of facility safety documentation, it is important to recognize which standard the design meets.

There are restrictions for fabrication of older packaging designs and on their use for import and export. Since the tests changed over the years, credit cannot be given to older designs for passing the dynamic crush test that is in the current regulations. This is an important consideration when using these packagings to store material and when evaluating their integrity for facility safety documentation.

Title 10 CFR Part 71.19 states the restrictions for use of older packaging designs. These restrictions are summarized below.

- Type B(U) and B(M) Packaging (1973 IAEA Standards)
  - The packaging must have been manufactured before April 1, 1999.
  - It requires multilateral approval for export, and some countries may not grant Competent Authority Approval for these designs.
- Type B -85 Designation (1985 IAEA Standards)
  - The packaging must have been manufactured before December 31, 2006.
  - It requires multilateral approval for export, but the design is acceptable to most countries.

### Additional Restrictions for Fissile Shipments by Air

Title 10 CFR Part 71.55(f) contains the additional tests and performance criteria for fissile material packages that will be offered for commercial air transport. The NRC added additional tests to address the high-impact forces that can occur during an airplane crash. Consequently, the following additional tests are required for these packagings:

- An enhanced puncture test.
- The thermal test in Section 71.73(c)(4) has an extended duration of 60 minutes.
- The contents must be shown to remain subcritical when subjected to an impact onto an unyielding surface at a velocity of 90 meters per second.

*NOTE: There are very few packaging designs that meet these additional air requirements. Shippers must take care to check the Certificate of Compliance issued for these packagings and ensure that the certificate contains wording specifically authorizing shipment by air. Generally, fissile material packaging approvals to the 1967–1985 IAEA standards will not be authorized for air transport.*

### Additional Restrictions for Plutonium Shipments By Air

Title 10 CFR Parts 71.63 and 71.64 contain additional requirements for packaging designed for air transport of Pu. The accident testing requirements for this type of packaging are detailed in 10 CFR 71.74. In addition, DOE has requirements in 10 CFR 871 and DOE Order 460.1B for Pu shipments by air. As with fissile material packaging, few designs are approved for air transport of Pu. One authorized packaging is the PAT-1, USA/0361/B(U)F-96.

## 7.22 REVIEW QUESTION SET 9

1. What are the differences between the design and testing requirements for:

   - IP-2 packaging and Type A packaging?

     **IP-2 only has 2 of the Type A Tests: Drop and Stacking**

   - IP-3 packaging and Type A packaging?

     **IP-3 is identical to Type A authorized for solids. Type A for liquids has additional requirements.**

2. What are the recordkeeping requirements for:

   - IP: **173.411(c) Maintain the testing data for 1 year after shipment**

   - Type A Packaging: **173.415(a) Maintain the testing data for 1 year after shipment**

3. What section of the DOT regulations allows DOE to certify Type B and fissile material packaging?

   **173.7(d)**

4. What marking requirements are required on a DOT 7A packaging under Section 178.350?

   **USA DOT 7A Type A**
   **Section 178.3(a)(2) Name/Address or Symbol of the Manufacturer (Shipper)**

5. What section of 10 CFR contains the design and construction requirements for Type B(U) and B(M) packaging?

   **10 CFR 71, Subpart F**

6. What section of 49 CFR contains the testing requirements for Type A packaging?

   **173.465**

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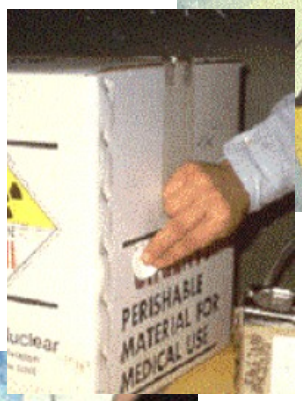
# CHAPTER 8
# CONTROLS FOR RADIOACTIVE MATERIAL SHIPMENTS

OBJECTIVES

- UNDERSTAND HOW TO DETERMINE AND USE THE TI.
- UNDERSTAND HOW TO DETERMINE AND USE THE CSI.
- DETERMINE THE APPLICABLE RADIATION LEVELS FOR PACKAGES AND SHIPMENTS.
- DETERMINE THE APPLICABLE CONTAMINATION LEVELS FOR PACKAGES AND VEHICLES.

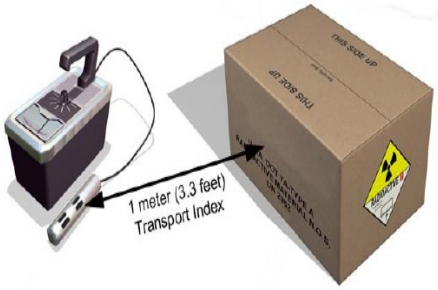


## 8.1 INTRODUCTION

Controls, combined with packaging, provide for safe radioactive material shipments and also achieve the principles of ALARA. These controls are the TI, the CSI, dose rate limits, contamination limits, exclusive use provisions, and use of a closed transport vehicle.

## 8.2 TRANSPORT INDEX

The dose rates associated with radioactive material shipments are controlled, in part, by the TI. The TI is a dimensionless number that restricts the number of radioactive material packages that can be safely accumulated on a conveyance or in a storage area. By definition, the TI is the maximum radiation level in mrem/hr at 1 meter from the package surface. (If using instrumentation that reads in the SI units, multiply the reading in mSv by 100 to get the TI.) The TI is rounded to the nearest tenth and is shown, without units, as the TI on shipping papers and radioactive material labels.




*NOTE: You may have a TI of 0.0. A TI between 0.0 and 0.05 may be taken as zero.*

The TI is used by carriers and transport workers who store and transport groups of radioactive material packages. For nonexclusive use shipments, the total TI is restricted to 50, thereby limiting the radiation levels around a group of packages.

There are additional restrictions on the allowable TI for packages offered by passenger air. See Sections 173.448(e) and 175.700 and the USG 01 and 10 in the IATA regulations. For water shipments, see Section 176.704, as well as Section 7.2.9 in the IMDG Code.

## 8.3 CRITICALITY CONTROL

In the transport system, criticality safety is achieved by a combination of mass restriction and packaging design. The requirements aim to ensure that the package or array of packages will remain subcritical under all credible transport conditions.

Packages containing fissile-excepted material under Section 173.453 do not require any criticality controls because the mass or concentration of fissile material has already been restricted by the requirements in this section such that a criticality is not possible. The additional requirements for fissile material packages are imposed to ensure that the contents remain subcritical under normal and accident transport conditions.

Sections 173.457–459 detail the requirements for criticality control of fissile material packages during transport. Criticality control is reflected by assigning the CSI, and this value is shown on the FISSILE label and on the shipping documentation. The CSI is a number used to provide criticality safety by restricting the number of fissile packages and, consequently, the fissile mass allowed on a conveyance. Nonexclusive use shipments are restricted to a total CSI of 50. Exclusive use shipments may have a total CSI of up to 100.

### CSI Determinations

Determination of the CSI depends on the packaging used. The CSI determination when using the DOT 7A packaging is found in 10 CFR 71, Subpart C. For fissile material packaging approved by the NRC or DOE, the CSI is stated in the packaging certificate.

*CSI Determination for the DOT 7A*

In 10 CFR 71.22(e), there is an equation to calculate the CSI for the package. The values for X, Y, and Z are the allowable mass limits for $^{235}U$, $^{233}U$, and Pu, respectively, as found in either Table 71-1 or Table 71-2, as appropriate.

$$CSI = 10\left[\frac{\text{grams of } ^{235}U}{X} + \frac{\text{grams of } ^{233}U}{Y} + \frac{\text{grams of Pu}}{Z}\right]$$

*CSI Determination for NRC- and DOE-Approved Packaging*

The types of packaging that have been certified for fissile contents by either the NRC or DOE have a Certificate of Compliance issued by the respective entity. The certificate will specify the assigned CSI; it generally will be found in Section 5 of the certificate.

5.(b)(1) Contents (continued)

Table 2: Loading Limits for Solid Metal or Alloy in the

| Uranium Enrichment (weight percent U-235) | CSI | With Maxim U-2 |
|---|---|---|
| | | Per Convenience Can |
| > 90 and ≤ 95 | 0.0 | 0.879 |
| | 0.4 | 1.758 |
| | 0.8 | 3.516 |
| | 2.0 | 5.568 |

There are additional restrictions on the allowable CSI for packages offered by passenger air. See Section 175.700 and USG 01 and 10 in the IATA regulations. For water shipments, see Section 176.704 and Section 7.2.9 in the IMDG Code.

## 8.4 EXCLUSIVE USE AND CLOSED TRANSPORT VEHICLE PROVISIONS

Throughout the regulations, there are times when the exclusive use provisions or use of a closed transport vehicle is required. These are generally cases where higher dose rates or contamination levels are present or there is a need to compensate for a lower-integrity package.

As defined in Section 173.403, *exclusive use* is a contractual arrangement between the shipper and the carrier which, in part, ensures that only personnel having radiological training will come into contact with the radioactive cargo. A *closed transport vehicle*, by definition, requires an enclosure that restricts access by the general public to the surfaces of the radioactive material packages.

### Exclusive Use Definition

*Exclusive use* (also known as "sole use" or "full load") is defined in 49 CFR 173.403. Important aspects of the definition are as follows:

- Exclusive use, by definition, requires a single consignor (shipper), and it gives the shipper sole use of a conveyance. This does not preclude multimodal shipments or consignments with multiple pickup or delivery locations. However, care must be taken to ensure that all the exclusive use provisions are met for these types of shipments.

- It is a contractual agreement between a single shipper and carrier, and it has responsibilities for both the shipper and the carrier. The shipper is required to provide certain information to the carrier, and the carrier is required to maintain certain controls, as directed by the shipper, while the shipment is in transit.

- Any loading/unloading is conducted as directed by either the shipper or consignee, and it must be conducted by personnel with radiological training and appropriate equipment to deal with the radiological aspects of the shipment. This requirement is communicated to the carrier by the shipper. Within DOE, the loading and unloading are generally conducted by contractor personnel who are radiological workers. A broader implication of this

requirement is that if there are any incidents with the shipment in transit, trained radiological workers must be dispatched to the scene to assess the situation and conduct any loading/unloading operations.

- The shipper must provide the carrier with written instructions for maintenance of exclusive use controls. (See Sections 173.403, 173.427(a)(6)(iv) and 173.441(c).) Also, shipping papers are required to have a notation that the shipment is consigned as exclusive use whenever exclusive use is required under the regulations. (See Section 172.203(d)(9).) The information in the written instructions to the carrier must include the following:

    - If applicable, it must include a statement that the vehicle survey in Section 173.443(c) is required. This vehicle survey is required when shipments are made using Section 173.443(b), which allows for higher contamination levels on the surface of a package. The survey ensures that vehicles are returned to general service at the same cleanliness levels as other vehicles that carry radioactive material packages with surface contamination levels that meet the limits in Section 173.443, Table 9. ***NOTE: Dedicated transport vehicles operating under the provisions in Section 173.443(d) are not subject to this survey until they are released back to general service.***

    - Statements must be included that direct the carrier to avoid actions that will unnecessarily delay delivery or will result in increased radiation levels or exposures to transport workers and the general public. This is required when shipping under Section 173.441(b), which allows for higher radiation levels. (See Section 173.441(c).) This requirement may be met by detailing the specific routing and the locations of safe havens to be used in the event of unexpected delays due to weather or road conditions.

### When is Exclusive Use Required?

As seen in the definition, exclusive use provisions give shippers considerable control over a shipment. It also significantly restricts access and exposure times to radioactive material packages by transportation workers and the general public. Exclusive use also reduces the number of times a package is handled during transportation, as opposed to the multiple handling opportunities afforded by mixed load (nonexclusive use) shipments.

Therefore, the following are typical shipping conditions that require exclusive use:

- Package with surface dose rates exceeding 200 mrem/hr or with a TI greater than 10. (See Section 173.441(b).) ***NOTE: Packages with surface dose rates exceeding 200 mrem/hr must be shipped in a closed transport vehicle in addition to being offered as exclusive use.***
- Package expected to have removable contamination (while in transit) above the limits in Section 173.443, Table 9. (See Section 173.443(b).)
- Package with CSI >50. (See Section 173.457(c).)
- Consignment with total TI >50. (See Section 173.441(d).)
- Consignment with total CSI >50. (See Sections 173.457(d) and (e).)
- Use of lower-integrity packaging for LSA materials and SCO. (See Sections 173.427(b)(1), (4), and (5), as well as Section 173.427(c)(2).)
- Required as an operational control in a Special Permit. For example, see Special Permit 14267.

## 8.5 RADIATION LEVELS

Allowable dose rates for packages and conveyances are provided in Section 173.441. The dose limits for excepted packages are located in Sections 173.421, 424, 426, and 428. These limits are significantly lower (0.5 mrem/hr) than what is allowed for other radioactive material packages. The 0.5 mrem/hr surface dose rate for excepted packages was established to ensure that sensitive photographic material will not be damaged and that any radiation dose to transport workers and the public will be insignificant.

For nonexcepted packaging, radioactive material packages are restricted to surface readings not exceeding 200 mrem/hr and a maximum TI of 10. These limits apply for nonexclusive use shipments and help to ensure that transport personnel do not receive significant doses, even when frequently handling a large number of packages.

The TI limit of 10 was originally established based on an assumed transit time and conventional separation distances between packages containing radium sources being shipped via the U.S. Railway Express Company in 1947. This limit would yield a dose of approximately 10 mrem (at a distance of 15 feet over a 24-hour period).

The surface dose rate limit of 200 mrem/hr considered personnel exposures to a transport worker carrying packages close to the body for a period of time each day. The worker's exposure was not to exceed the then permissible dose of 100 mrem per 8-hr working day. This was considered to be a conservative limit for transportation, as workers would have much shorter exposure times.

Care must be taken when designing and loading radioactive material packaging to ensure that the radiation levels will not increase during transport. For example, heavy inner packaging may shift in transit if it is centered within the outer packaging using lightweight material, resulting in higher readings on the bottom of the package surface as a result of settling.

Radiation level limitations from Section 173.441 are shown in Figure 8-1 on the following page. Packages may be offered with higher dose rates if additional controls are placed on the shipment. For packages with up to 200 mrem/hr readings at the surface and a TI exceeding 10, the shipment may be placed under exclusive use. This changes the 10 mrem/hr restriction to be at 2 meters from the outer edge of the vehicle. Radioactive material packages may have a surface reading as high as 1000 mrem/hr if they are placed under exclusive use and in a closed transport vehicle. In this case, the surface of the access-limiting enclosure cannot exceed 200 mrem/hr. The limits on radiation levels of a package offered for transport and the various vehicle configurations are shown in Figures 8-2, 8-3, and 8-4 on the following pages. Following the figures is a summary of the radiation levels for packages and transport vehicles in Table 8-1.

## Radiation Level Limitations (173.441)

- Mixed Load
  - Package < 200 mrem/hr
  - TI < 10
- Exclusive Use
  - Package < 200 mrem/hr
  - Vehicle < 200 mrem/hr
  - 2 meters from Vehicle < 10 mrem/hr
  - Occupied Space < 2 mrem/hr
- Exclusive Use, Closed Transport Vehicle
  - Package < 1000 mrem/hr
  - Vehicle < 200 mrem/hr
  - 2 meters from Vehicle < 10 mrem/hr
  - Occupied Space < 2 mrem/hr

**Figure 8-1. Radiation level limitations (Section 173.441)**

*NOTE: In determining the radiation levels, contributions from neutrons must be added to the βγ dose rate. See the definition of radiation level in Section 173.403 for the flux density conversions.*

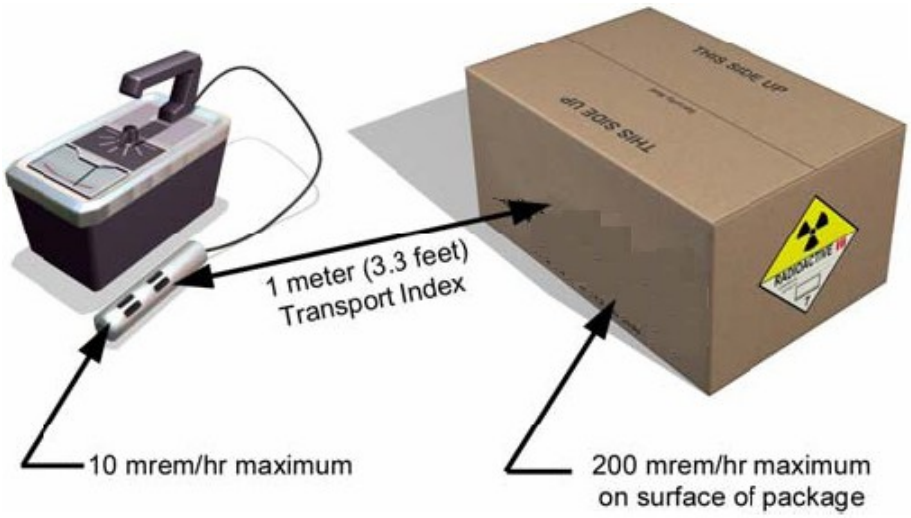



**Figure 8-2. Dose rates at surface and 1 meter for nonexclusive use shipments**

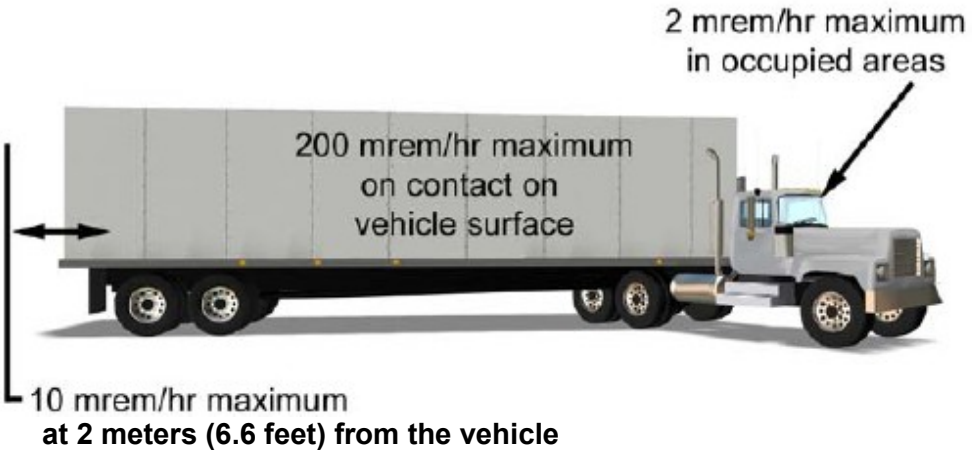



**Figure 8-3. Allowable dose rates for an exclusive use shipment**

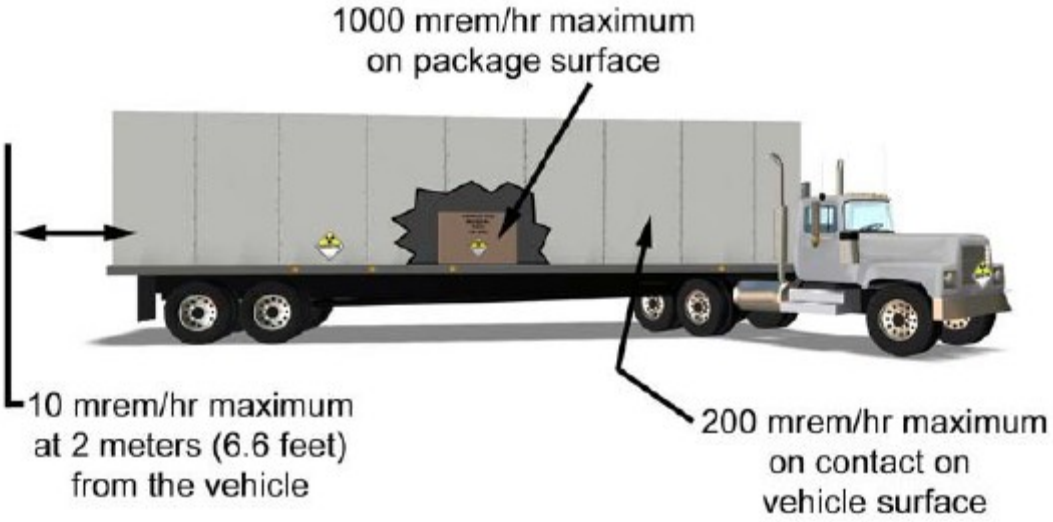



**Figure 8-4. Allowable dose rates for an exclusive use shipment in a closed transport vehicle**

**Table 8-1. Summary of Radiation Levels for Packages and Transport Vehicles**

| Package and Vehicle Radiation Level Limits (49 CFR 173.441)[1] | | | | |
|---|---|---|---|---|
| | | Nonexclusive Use Shipment | Exclusive Use Shipment | |
| | | Open or Closed Transport Vehicle | Open (flat-bed) | Closed Transport Vehicle |
| Package Limits: | External Surface | 2 mSv/hr (200 mrem/hr) | 2 mSv/hr (200 mrem/hr) | 10 mSv/hr (1000 mrem/hr) |
| | Transport Index (TI)[2] | 10 | No limit | |
| | Criticality Safety Index (CSI)[5] | 50 | No limit | |
| Transport Vehicle Limits (highway and rail): | Any point on the outer surface | N/A | N/A | 2 mSv/hr (200 mrem/hr) |
| | Vertical planes projected from outer edges | | 2 mSv/hr (200 mrem/hr) | N/A |
| | Top of | | Load: 2 mSv/hr (200 mrem/hr) | Vehicle: 2 mSv/hr (200 mrem/hr) |
| | 2 meters from | | Vertical Planes: 0.1 mSv/hr (10 mrem/hr) | Outer Lateral Surfaces: 0.1 mSv/hr (10 mrem/hr) |
| | Underside | | 2 mSv/hr (200 mrem/hr) | |
| | Occupied position | N/A[3] | 0.02 mSv/hr (2 mrem/hr)[4] | |
| | Sum of package TIs | 50 | No limit | |
| | Sum of package CSIs[5,6] | 50 | 100 | |

1. The limits in this table do not apply to excepted packages. [173.421, 173.424, 173.426, and 173.428]

2. The dimensionless number equivalent to maximum radiation level at 1 meter (3.3 feet) from the exterior package surface is in mrem/hr rounded up to the next tenth. [173.403]

3. No dose limit is specified, but separation distances apply to packages with RADIOACTIVE YELLOW-II, RADIOACTIVE YELLOW-III, or CSI labels. [177.842]

4. Does not apply to carriers if operating under a state or federally-regulated radiation protection program and if personnel wear radiation dosimetry devices. [173.441(b)(4)]

5. These provisions do not apply to shipment by vessel. See Sections 176.700–720 for the vessel requirements.

6. The number of packages containing fissile material stored in transit in any one storage area must be limited so that the total sum of the CSIs is ≤50 and such groups of packages must be spaced at least 6 meters (20 feet) from other such groups. [173.457 and 173.459]

## 8.6 CONTAMINATION LIMITS

### Package Contamination Limits

Removable contamination on the surface of radioactive material packages must meet the principles of ALARA. The maximum removable surface contamination limits are stated in Section 173.443, Table 9, and are expressed in dpm/cm$^2$.

The contamination limits have remained largely unchanged for several decades. The limits were originally established in the 1960s based on recommendations by the 1959 International Commission on Radiological Protection and the allowable exposure levels for laboratory and plant workers (100 mrem/week; 8 hour days). These levels were seen to be reasonably conservative for transportation workers due to the significantly shorter exposure times.

The DOT contamination limits are based on whether the contaminant is a βγ and/or a low-toxicity α emitter or a high-toxicity α emitter. The definition of a low-toxicity α emitter is provided in Section 173.403. By definition, the DOT considers enriched U to be a high-toxicity α emitter.

The levels in Table 9 of Section 173.443 are the surface limits for removable contamination. Most DOE contractors use smears to assess the removable contamination levels. It is assumed that the smear technique has 10% efficiency. That is, activity on a wipe represents on 10% of the total nonfixed contamination present on the surface. Therefore, shippers should multiply the smear data by 10 before comparing it to the Table 9 limits. Since smears are commonly used and recorded in dpm/100 cm$^2$, shippers should be careful to ensure that they covert to the appropriate units before making comparisons between the smear data and the values in Table 9.

If a technique other than smears is used to assess the removable contamination and a higher efficiency can be documented, then the higher values could be applied. Regardless, at no time during transport may contamination levels exceed 10 times the levels in Table 9, "Non-Fixed External Radioactive Contamination Limits." See Figure 8-5.

| | Maximum Permissible Limits | | |
|---|---|---|---|
| Contaminant | Bq/cm$^2$ | mCi/cm$^2$ | dpm/cm$^2$ |
| • Beta and gamma emitters and low-toxicity alpha emitters | 4 | $10^{-4}$ | 220 |
| • All other alpha-emitting radionuclides | 0.4 | $10^{-5}$ | 22 |

Important Notes:

- For assessment by wipe method, 300 cm$^2$ is smeared.
- Limits in the table are SURFACE limits. Wipe efficiency is assumed to be 10% and must be taken into account when comparing with the smear data.

**Figure 8-5. Maximum removable surface contamination levels in Table 9 (Section 173.443)**

The contamination limits in Table 9 of 49 CFR apply to all nonexclusive use shipments of radioactive material packages. For packages shipped as exclusive use shipments by rail or highway, the removable (nonfixed) radioactive surface contamination at any time during transport may not exceed 10 times the limits for nonexclusive use shipments.

This provision allows for the phenomenon called *weeping*. Under certain conditions, packages will have fixed contamination that will migrate, or weep, to the outer surface and become removable. For example, contaminants such as $^{137}$Cs may adhere onto or penetrate into steel surfaces. The contamination may become ingrained in pores, fine cracks, and crevices, particularly near the lid and seals of a package. Subsequent weathering and exposure to moisture can cause some of this fixed contamination to be released and increase the removable contamination levels. Section 173.443(b) allows for this increase in the contamination levels, as long as all three of the following conditions are met:

- The levels do not exceed the Table 9 limits at the beginning of transport.
- The shipment is made as exclusive use.
- The level of contamination at the end of transport does not exceed 10 times the values in Table 9.

The only time a radioactive material package may have removable contamination levels above those in Table 9 at the beginning of transport is when the package is transported by exclusive use utilizing a dedicated conveyance (stenciled with the words *For Radioactive Materials Use Only*) in accordance with Section 173.443(d). Under these conditions, the package can have removable contamination up to 10 times the levels in Table 9, but it may not exceed these levels at any time during transport.

There are no limits set for the fixed contamination on packages, as this will be controlled by the dose rate.

***NOTE: Under the international air and water regulations, the allowances for higher contamination levels specified in Sections 173.443(b) and (d) do not exist.***

### Transport Vehicle Contamination Surveys

Vehicles transporting exclusive use shipments of radioactive material packages under the provisions of Section 173.443(b) must be surveyed with the appropriate radiation detection instruments after each use. The vehicle must not be returned to service until the external radiation on each accessible surface does not exceed 0.5 mrem/hr (0.005 mSv/hr) and the removable surface contamination does not exceed the limits in Table 9. (See also Section 177.843.)

An exception to this vehicle survey requirement is found in Section 173.443(d). This section allows for removable contamination levels on package surfaces up to 10 times the Table 9 limits. In addition, the vehicles do not have to be decontaminated to the Table 9 limits until they are released back to general service. This section applies to closed highway or rail transport vehicles that are dedicated solely to the transport of radioactive packages and are appropriately marked on the exterior as dedicated vehicles with the words *For Radioactive Materials Use Only*. In such cases, the removable surface contamination on the packages may be as high as 10 times the limits in Table 9 at the beginning of transport.

There is comparable language in each of the modal sections. See Sections 177.843, 174.715, and 175.705 for contamination levels on conveyances by highway, rail, and air, respectively.

DOE contractors should note the differences between the values in Table 9 and the values stated in DOE directives and regulations. See the DOE contamination limits from 10 CFR 835 on the following page in Figure 8-6. Following the figure is a summary of the contamination limits for packages and transport vehicles in Table 8-2.

SURFACE CONTAMINATION VALUES[1] IN DPM/100 CM[2]

| Radionuclide | Removable[2 4] | Total (Fixed + Removable)[2, 3] |
|---|---|---|
| U-nat, U-235, U-238, and associated decay products | [7] 1,000 | [7] 5,000 |
| Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129 | 20 | 500 |
| Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133 | 200 | 1,000 |
| Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above[5] | 1,000 | 5,000 |
| Tritium and tritiated compounds[6] | 10,000 | N/A |

[1] The values in this appendix, with the exception noted in footnote 5, apply to radioactive contamination deposited on, but not incorporated into the interior or matrix of, the contaminated item. Where surface contamination by both alpha-and beta-gamma-emitting nuclides exists, the limits established for alpha-and beta-gamma-emitting nuclides apply independently.

[2] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[3] The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 $cm^2$ is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the surface contamination value if: (1) From measurements of a representative number of sections it is determined that the average contamination level exceeds the applicable value; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 $cm^2$ area exceeds three times the applicable value.

[4] The amount of removable radioactive material per 100 $cm^2$ of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note—The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 $cm^2$ is determined, the activity per unit area shall be based on the actual area and the entire surface shall be wiped. It is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

[5] This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

[6] Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface contamination value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore, a "Total" value does not apply.

[7] (alpha)

**Figure 8-6. DOE contamination limits from 10 CFR 835**

**Table 8-2. Summary of Package and Vehicle Contamination Limits (49 CFR 173.443)**

## Package and Vehicle Contamination Limits (49 CFR 173.443)

**NOTE:** All values for contamination in the DOT regulations are to be averaged over each 300 $cm^2$. Sufficient measurements must be taken in the appropriate locations to yield representative assessments. Wipe efficiency must be determined in accordance with Section 173.443(a)(1) or assumed to be 10%.

Table 9, Removable Contamination Limits (173.443)

| | Maximum Permissible Limit | | |
|---|---|---|---|
| Beta emitters, gamma emitters, and low-toxicity emitters | 4 $Bq/cm^2$ | 1 x $10^{-4}$ $\mu Ci/cm^2$ | **220 $dpm/cm^2$** (22,000 dpm/100 $cm^2$) |
| All other alpha emitters (i.e., other than low-toxicity alpha emitters) | 0.4 $Bq/cm^2$ | 1 x $10^{-5}$ $\mu Ci/cm^2$ | **22 $dpm/cm^2$** (2200 dpm/100 $cm^2$) |

### The following exceptions from the above limits exist when the stated conditions are met:

For exclusive use shipments, the removable contamination on a package:

- May not exceed the values in Table 9 at the beginning of transport. [173.443(b)]
- May not exceed 10 times the values in Section 173.443(a) during transport. [173.443(b)]

The vehicle must not be returned to service until the radiation level is shown to be ≤0.005 mSv/hr (0.5 mrem/hr) at any accessible surface and there is no significant removable (nonfixed) contamination (Table 9 limits). [173.443(c)]

In a closed transport vehicle used solely for transporting radioactive materials packages, the contamination levels on the packages may not exceed 10 times the values in Table 9.

Additional conditions include:

- A survey of the interior surfaces of the empty vehicle must show that the radiation level at any point does not exceed 0.1 mSv/hr (10 mrem/hr) at the surface or 0.02 mSv/hr (2 mrem/hr) at 1 meter (3.3 feet).
- The exterior of the vehicle must be conspicuously stenciled with the words *For Radioactive Materials Use Only* in letters at least 76 mm (3 inches) high on both sides of the exterior.
- The vehicle must be kept closed except for loading and unloading. [173.443(d)]

Excepted package–empty packaging [173.428]

- Internal contamination may not exceed 100 times the Table 9 limits. [173.428(c)]
- External contamination on the package may not exceed the Table 9 limits. [173.428(a)]
- The radiation level must be ≤0.005 mSv/hr (0.5 mrem/hr) at any external surface. [173.428(a)]
- The package must be marked with *UN 2908* in accordance with Section 173.422(a).
- The packaging must be in unimpaired condition and securely closed to prevent leakage. [173.428(b)]
- The labels must be removed, obliterated, or covered, and the EMPTY label affixed to the packaging. [173.428(d)]
- The package contains no fissile material unless it is fissile excepted.

After any incident involving spillage, breakage, or suspected radioactive contamination, the modal-specific DOT regulations (i.e., Section 174.750(a) for railway, Section 175.700(b) for air, and Section 177.843(c) for highway) specify that vehicles, buildings, areas, or equipment have "no significant removable surface contamination" before being returned to service or routinely occupied. The carrier must also notify the offeror at the earliest practicable moment after each incident. In the event of certain hazardous materials incidents, the regulations (Sections 171.15 and 171.16) specify the criteria for immediate notice and detailed hazardous material incident reports.

## 8.7 REVIEW QUESTION SET 10

1. What is the purpose of the TI?

   It is used by the carrier to restrict the number of packages (and dose rate) accumulated on a conveyance and for separation/segregation determinations.

2. What is the maximum CSI allowed per conveyance:

   - By highway and rail, nonexclusive use: 50 173.457(d)
   - By highway and rail, exclusive use: 100 173.457(e)

3. The radiation dose rate at any point on the surface of an excepted package cannot exceed what value?

   0.5 mrem/hr 173.421(a)(2)

4. You have an LSA shipment consisting of contaminated soil packed in metal boxes. The soil is contaminated with depleted U. The removable contamination levels on the surface of the boxes are as high as 150,000 dpm/100 $cm^2$. Under what conditions can this shipment be legally transported?

   Have: 1500 dpm/$cm^2$
   Either decontaminate to Table 9 limits or ship under Section 173.443(d) in a closed transport vehicle that is dedicated for radioactive material use only.

5. A DOE contractor uses a private motor carrier to transport a series of high-level radioactive waste shipments. Based on the shipping cask design and anticipated activity loading, the radiation levels in the cab of the vehicle are expected to be between 3–5 mrem/hr. Under what provisions can this configuration legally be transported?

   Section 173.441(b)(4) Can exceed 2 mrem/hr if the driver is monitored under the state/federal radiation protection program.

6. What is the maximum TI per conveyance?

   - By highway and rail, nonexclusive use: 50 173.441(d)(1)
   - By highway and rail, exclusive use: No limit as long as 173.441(b) is met
   - By passenger air: 50 175.700(a)(5)
   - By cargo air: 175.702 (or 200 if exclusive use)

7. What is the maximum TI allowed for a package offered by passenger air?

   175.700(a)(1) 3.0 IATA USG 10(b)

8. Under conditions normal to transport, the radiation level for a nonexclusive use shipment must not exceed what level at any point on the surface of the package?

   200 mrem/hr 173.441(a)

9. What maximum level of radiation is permitted at 1 meter (3.3 feet) from the external surface of the package in a nonexclusive use shipment?

   10 mrem/hr 173.441(a)

10. For an exclusive use, closed vehicle shipment, what is the maximum surface reading permitted on the external surface of the package?

    1000 mrem/hr 173.441(b)(1)

11. For an exclusive use, closed-vehicle shipment, the radiation reading at any point on the surface of the vehicle must not exceed what level?

    200 mrem/hr 173.441(b)(2)

12. For an exclusive use, closed-vehicle shipment, the radiation reading at 2 meters from the outer lateral surface of any point on the transport vehicle must not exceed what level?

    10 mrem/hr 173.441(b)(3)

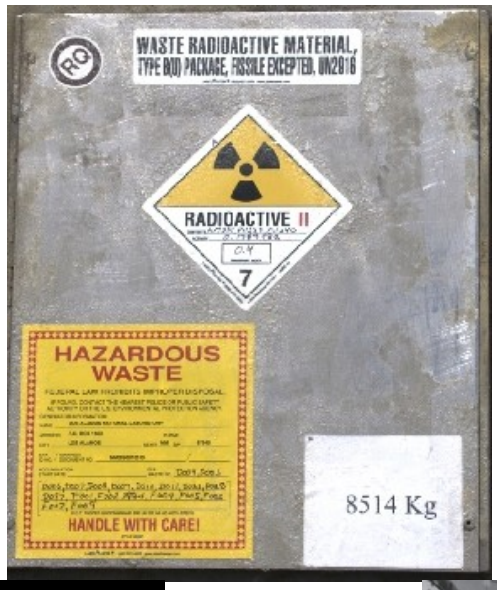
13. What radiation levels are permitted in any normally occupied space, except for private carriers, if the exposed personnel are wearing dosimetry devices and operate under the provisions of a regulated radiation protection program?

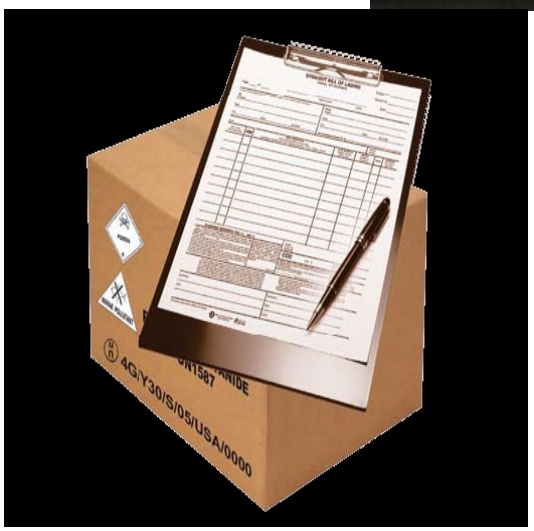
    2 mrem/hr 173.441(b)(4)

# CHAPTER 9
# COMMUNICATION

OBJECTIVES

- UNDERSTAND AND APPLY THE MARKING REQUIREMENTS.
- UNDERSTAND AND APPLY THE LABELING REQUIREMENTS.
- UNDERSTAND AND APPLY THE PLACARDING REQUIREMENTS.
- UNDERSTAND AND APPLY THE SHIPPING PAPER REQUREMENTS.



## 9.1 INTRODUCTION

The communication requirements of 49 CFR 172 are designed to complement the basic safety requirements for package activity limitation and package integrity. Historically, 49 CFR 172 has addressed the conventional communication requirements, such as 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, hazardous material employee training, and security for hazardous material shipments.

Package markings and labels and vehicle placards all serve to communicate to workers and the public the presence of radioactive material in the transport system. Shipping documentation provides a more complete picture of the shipment, and it provides additional information that is helpful to emergency response personnel. There are numerous exceptions to the marking, labeling, and placarding requirements. The general requirements are summarized below.

## 9.2 MARKING REQUIREMENTS

General marking requirements for all hazardous material packages are provided in 49 CFR 172.301, with additional requirements for specific commodities and packaging types detailed in Sections 172.302–338. The specific requirements for Class 7 material are located in Section 172.310.

Generally, packages of hazardous material are marked with the proper shipping name of the material, the UN ID number of the material, and the name and address of the consignee or consignor. All required markings must be durable, in English, and displayed in a manner so as not to obscure them or reduce their effectiveness. Markings may either be printed on the surface of the package itself or on a label, tag, or sign. (See Section 172.304.) Any package containing a material shipped using a shipping name with a "G" in Column 1 must also be marked with the technical name of the material in parentheses. For example, “Corrosive liquid, n.o.s. (Capyrlyl chloride).”

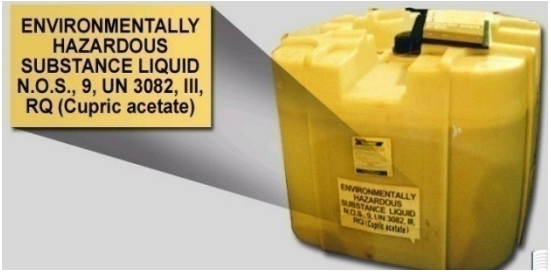
While there are some exceptions, general package marking requirements include the following:

- Proper shipping name.
- UN ID number.
- Names/addresses of consignee/consignor.
- The word *Waste* if the material is a hazardous waste.
- Technical names for generic proper shipping names.
- DOT-SP or DOT-E entries for special permits and exemptions.
- RQ and technical name, if needed for hazardous substances.
- The words *Inhalation Hazard*, if appropriate.
- The words *Marine Pollutant* (for bulk packages, some exceptions apply).
- The word *Biohazard* for infectious substances.
- Orientation arrows for liquids (for nonbulk combination packaging, some exceptions apply).
- Limited quantities require the UN ID number to be shown in a diamond (square on point) marking.

### Hazardous Waste

In addition to the DOT marking requirements, packages of hazardous waste are also required to be marked as specified in 40 CFR 362.32.

### Hazardous Substances




Marking hazardous substance packages is covered in Section 172.324. There are requirements for marking the RQ and for identifying the technical constituents.

*NOTE: There is an exception in Section 172.324 for radioactive material.*

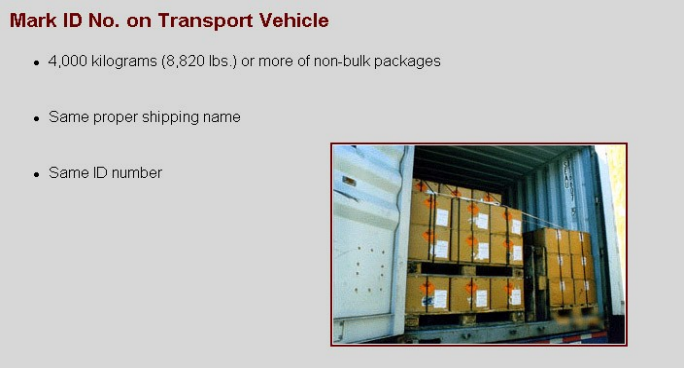
### Polychlorinated Biphenyls

In addition to the marking requirements for Class 9 material under the DOT regulations, the marking requirements for PCB material are specified in 40 CFR 761.40–45.

### Large Quantities of a Single Hazardous Material in Nonbulk Packages

The requirements for UN ID number marking for large quantities of a single hazardous material in nonbulk packages are located in Section 172.301(a)(3).

*NOTE: This section does not apply to Class 7 material.*




### Packaging Transported under a DOT Special Permit (Formerly Known as an Exemption)

Unless excepted by the special permit, packages transported under a DOT special permit must be marked in accordance with Section 172.301(c). For DOT exemptions issued before October 1, 2005, this requires the package to be marked with *DOT-E* and the exemption number. The package must be marked with *DOT-SP* and the permit number for special permits issued by the DOT on or after October 1, 2005.

## 9.3 RADIOACTIVE MATERIAL PACKAGE MARKING

Marking for all nonbulk hazardous materials packaging includes the following, although some exceptions apply: (1) Proper shipping name, (2) UN ID number, (3) names/addresses of the consignee/consignor, and (4) RQ, as appropriate. In addition to these markings, radioactive material packages are subject to the following marking requirements:

- Gross weight if >50 kg (110 lb).
- Type A, Type B(U), or Type B(M), as appropriate. This relates to the packaging design, not the radioactive content.
- Type IP-1, IP-2, or IP-3, as appropriate.
- The letters *USA*, or if the packaging is not of United States origin, the international vehicle registration code for that country.
- The applicable DOT specification number or the NRC or DOE package certificate number, as specified in the DOT specification or relevant certificate, e.g., USA DOT-7A or USA/9166/B(U)-85.
- For Type B(U) and B(M) packages, the trefoil radiation symbol.
- Each fissile material package or Type B(U) or B(M) package destined for export must be marked with the letters *USA*.

A summary of the marking requirements for radioactive material packages is shown in Table 9-1 on the following page. There are marking exceptions for domestic, exclusive use shipments of LSA material and SCO. (See Section 173.427(a)(6)(vi).) Limited quantity shipments also have marking exceptions. (See Sections 173.421 and 422.)

*Bulk packaging* for a hazardous material is defined in Section 171.8. The concept of bulk packaging reflected in that definition is that the packaging may involve the vehicle itself, such as a freight container or other large, closed receptacle in which the hazardous material is loaded with no intermediate form of containment. Traditionally, the DOT has viewed Type A and Type B radioactive material packaging as nonbulk packaging. Bulk radioactive material packaging is, therefore, most likely to involve conveyances such as:

- Tightly closed trucks/vans or railcars containing contaminated soils and debris.
- Large bins or freight containers for solids.
- Tanks containing slurries or other liquid waste.

For such shipments, the bulk packaging must be marked on its exterior with the applicable UN ID number. (See Section 172.302.) When required for radioactive material, the UN ID number must be placed on an orange rectangular panel adjacent to the required RADIOACTIVE placard. (See Section 172.332.) According to Section 172.334(a), it may not be placed on the RADIOACTIVE placard in lieu of the word *Radioactive* for domestic shipments. However, this prohibition does not exist in the international regulations (IAEA and IMO).

The IATA requires all radioactive material packages (including excepted packages) to be marked with the full name and address of both the shipper and consignee and the gross weight if greater than 50 kg. See Section 10.7.1.3 in the IATA regulations. In the IMDG Code, see the similar provisions in Section 5.2.1.5.

**Table 9-1. Summary of Marking Requirements for Class 7 (Radioactive) Material Packages**

## Marking Requirements for Class 7 (Radioactive) Material Packages (49 CFR Part 172, Subpart D)

NOTE: The IAEA, ICAO, and IMO may require additional hazard communication information for international shipments.

### Markings Always Required

**Bulk Packages**

UN ID number on:

- orange panels [172.332(b)]
- white square-on-point display [172.336(b)]

**Nonbulk Packages**

- Proper shipping name [172.301]
- UN ID number [172.301]
- Name and address of consignor or consignee, *unless*:
  - Highway only and no motor carrier transfers, or
  - Part of carload or truckload lot or freight container load, and entire contents of railcar, truck, or freight container are shipped from one consignor to one consignee. [172.301(d)]

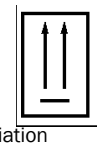
**Excepted Packages**

- Limited Quantity:
  - UN 2910 [173.422(a)]
  - RADIOACTIVE [173.421(a)(4)]
- Instruments and Articles:
  - UN 2911 [173.422(a)]
- Manufactured Articles containing natural U or Th:
  - UN 2909 [173.422(a)]
  - RADIOACTIVE [173.421(a)(4)]
- Empty Packaging:
  - UN 2908 [173.422(a)]

### Additional Markings Sometimes Required

**Material-Based Requirements**

Each package with a gross mass greater than 50 kg (110 lb) must have its gross mass, including the unit of measurement, marked on the outside of the package. [172.310(a)]



For a nonbulk combination package containing liquid, use underlined double arrows indicating the upright orientation, and place them on two opposite sides. [172.312 (a)–(c)]

For a hazardous substance in a nonbulk package, the letters *RQ* in association with the proper shipping name. [172.324(b)]

Shipments of LSA material or SCO consigned as exclusive use by Section 173.427 are excepted from the marking requirements (i.e., proper shipping name and identification number) except that the exterior of each package or unpackaged material must be marked with the words *Radioactive-LSA* or *Radioactive-SCO*, and *RQ*, as appropriate.

**Package-Based Requirements**

The package type for Type IP-1, Type IP-2, Type IP-3, Type A, Type B(U), or Type B(M), as appropriate, in letters 13 mm (0.5 inches) high or greater. [172.310(b)]

The words *USA DOT 7A Type A* for DOT 7A packaging. See Section 178.350 and the markings required by Section 178.3.

For NRC-approved Type B(U), B(M), or fissile material packages, the package identification marking from the Certificate of Compliance (e.g., USA/9166/B(U), USA/9150/B(U)-85). [173.471(b)]

For Type B(U) or B(M) package, the trefoil symbol per 49 CFR 172, Appendix B. [172.310(d)]

For IP-1, IP-2, IP-3, or a Type A package, the package must be marked with the letters *USA* or the international vehicle registration code of the country of origin for foreign designs. [172.310(c)]

For NRC-certified packages, the model number, gross weight, serial number, and package identification number. [10 CFR 71.85]

**Administrative-Based Requirements**

If a DOT special permit is being used, the outside of the package must be marked with *SP-*, followed by the exemption number. [172.301(c) and 172.302(c)]

For each Type B(U), B(M), or fissile material package destined for export, the letters *USA* in conjunction with the specification markings or certificate identification. [172.310(e)]

### Special Considerations/Exceptions for Marking

Markings must be (a) durable and printed in English on a package surface, label, tag, or sign, (b) displayed on a background of sharply contrasting color, (c) unobscured by labels or attachments, and (d) isolated from other marks (such as advertising). [172.304]

For bulk packages, markings (i.e., orange panels) may be required on more than one side of the package (see Sections 172.302(a) and 172.331(c)) and must be displayed in proximity to any required placards. [172.334(f)]

An overpack must have a statement that the contained packages comply with the prescribed specifications. [173.25(a)(4)]

## 9.4 REVIEW QUESTION SET 11

1. Required marking may be made in English or the language of the country to which the package is being shipped.

    - True
    - **False 172.304(a)(1)**

2. A nonbulk combination package containing 10 inside 1-pint containers of 6.1 poison liquid must have which of the following markings on it?

    a. Arrows indicating a pull tab for the opening.
    b. TURN ME OVER I'M LEAKING on the bottom of the package.
    **c. Arrows on two opposite vertical sides to indicate the upward position of the inside container. 172.312(a)(2)**
    d. Both b and c.

3. What marking is required on a package shipped under a DOT exemption or special permit?

    **DOT-E XXXX or DOT-SP XXXX 172.301(c)**

4. What are the markings required for a radioactive material offered

    - By highway as a limited quantity?

        **UN ID number, the word *Radioactive* on inner or outer packaging**
        **173.421(a) and (a)(4)**

    - By air as a limited quantity?

        **IATA 10.7.1.3 UN ID number, Gross Weight (>50 kg), Names/Addresses**

5. What markings are required for a Type A quantity radioactive material packaged in DOT 7A packaging? The gross weight of the package is 408 kg, and there is an RQ of the radioactive material.

    **RQ Radioactive Material, Type A Package UN2915**
    **408 kg USA DOT 7A Names/Addresses**
    **172.301–310; 178.350**

6. What markings are required for a Type B radioactive material package, Certificate of Compliance number USA/9216/B(U)F-85, that will be shipped domestically? There is an RQ amount of activity, and the gross weight of the package is 6810 kg.

    **RQ Radioactive Material, Type B(U) Package, Fissile UN3328**
    **6810 kg USA/9216/B(U)F-85 Names/Addresses Trefoil Symbol**
    **172.301–310**

## 9.5 GENERAL LABELING REQUIREMENTS

Although similar in color and shape, there is a difference between labels and placards. Generally, *labels* are applied to packages such as boxes and drums, and *placards* are applied to transport vehicles such as trucks and railcars. Labels are used to identify primary and subsidiary hazards and can also communicate handling precautions and prohibitions (e.g., CARGO AIRCRAFT ONLY label).

Sections 172.400–401 discuss the labels that a shipper must affix to packages, overpacks, or freight containers (if appropriate) prior to offering a package for transport that contains a hazardous material. Section 172.400(b) refers to Column 6 of the HMT. Column 6 of the HMT specifies the hazard warning label(s) required for a particular hazardous material. The initial step in determining the appropriate labeling requirements, if any, is to check the label codes indicated in Column 6. If Column 6 indicates *None*, then no label is required.

In certain instances, even though Column 6 of the HMT specifies a label, the label need not be affixed. Labeling might be excepted by some other section of the regulations, such as Section 172.400a or the packaging section for the material referenced in Column 8A in the HMT. All packaging exceptions should be read very closely to ensure that the exception applies to labeling for the commodity and mode of transportation.

### Label Placement

Section 172.406 details the requirements for displaying labels on packages.

## 9.6 ADDITIONAL LABELING REQUIREMENTS

Generally, the labeling requirements in Section 172.402 are in addition to the labeling specified in Column 6 of the HMT. For many materials listed in the HMT, more than one label is required to indicate the secondary hazards. Except for Class 1 or 2 material, the "Subsidiary Hazard Label Table" in Section 172.402(a) is used when the package is not already labeled in accordance with the primary and subsidiary labels specified in Column 6 of the HMT, Section 172.101. It is important to note that the chart is based on the packing group of the subsidiary hazard. For example, a Class 3

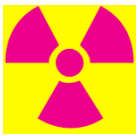
(flammable liquid) material, Packing Group II, which has a subsidiary hazard of Class 8 (corrosive), must have a FLAMMABLE label for the primary hazard and a CORROSIVE label for the subsidiary hazard. The "X" in the chart means this applies to all modes of transportation. Labels must display the hazard class or division number in the lower corner of the label. This display is required for both primary and subsidiary hazard labels.

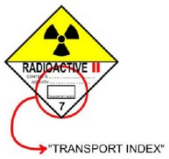
CARGO AIRCRAFT ONLY Label

The CARGO AIRCRAFT ONLY label is required on packages that are prohibited by regulation from being offered for transport aboard passenger aircraft. See 49 CFR 172.402(c) and Section 7.2.4.2 in the IATA regulations.

## 9.7 LABELING REQUIREMENTS FOR RADIOACTIVE MATERIAL

Radioactive material labeling is based on the maximum package surface dose rate and the TI, as shown in the table in Section 172.403. Shippers should carefully read the footnotes in the table and note the requirement that two labels must be placed on opposite sides (excluding the top and bottom) of a radioactive material package.






RADIOACTIVE YELLOW-II and RADIOACTIVE YELLOW-III labels have the TI indicated on the label. For fissile material packages, the FISSILE label with the CSI indicated is required. Two FISSILE labels must be placed adjacent to the two RADIOACTIVE labels on the package.

For radioactive material with subsidiary hazards, the required subsidiary labels must also be shown. (See Section 172.402(d).)

There are labeling exceptions for excepted packaging shipments and some LSA material and SCO shipments. Empty radioactive material packages shipped under Section 173.428 must be labeled with the EMPTY label.

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.

- RADIOACTIVE WHITE-I label – Indicates that the external radiation level is low and no special stowage controls or handling are required.
- RADIOACTIVE YELLOW-II and RADIOACTIVE YELLOW-III labels – Indicate that the package will have an external radiation level which requires consideration for stowage for during transport.
- RADIOACTIVE YELLOW-III label – Means the highway carrier must placard the transport vehicle with Radioactive placards when the packages are accepted from the shipper. By rail, the placards must be affixed by the shipper.
- FISSILE label – Indicates the material has properties relating to nuclear criticality safety and may require stowage controls for transport.

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

- Contents – Name of the radionuclides; for mixtures of radionuclides, use Section 173.433(f)

- Activity – Activity must be expressed in appropriate SI units (e.g., Bq, TBq, etc.)
- TI – For RADIOACTIVE YELLOW-II and RADIOACTIVE YELLOW-III labels

For the FISSILE label, the CSI must be entered on the label. Figure 9-1 provides additional examples of the RADIOACTIVE labels.

**Figure 9-1. Examples of RADIOACTIVE labels**

The key 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 Figure 9-2 below. The label table in Section 172.403 details which label is applicable based on these dose rates.

| 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).) |

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

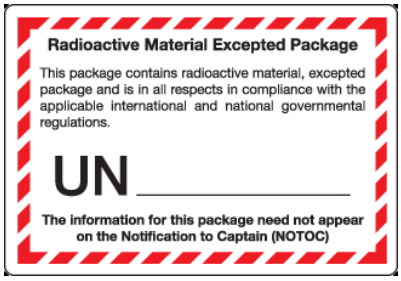
**Figure 9-2. Label category based on TI and surface radiation level**

When shipping by air, Section 10.7.4.3 requires radioactive material packages to bear two RADIOACTIVE labels <u>and</u> two of each of the following labels, as applicable:

- Subsidiary risk label (e.g., FLAMMABLE LIQUID label)
- FISSILE label
- CARGO AIRCRAFT ONLY label

For very small packages, including cylinders, one set of labels is allowed. The EMPTY label is not required under the IATA regulations or the IMDG Code.

Air shipments of excepted packages of limited quantity radioactive material are required to display a RADIOACTIVE MATERIAL-EXCEPTED PACKAGE label. See Sections 7.2.4.6 and 10.7.4.4.3 of the IATA regulations.




Air shipments of limited quantities of radioactive material that also contain excepted quantities of other hazard classes may be offered as excepted quantity shipments. These are similar to small quantity shipments under 49 CFR 173.4.

For 2009, the ICAO has proposed that packages with an excepted quantity be labeled with a newly designed label. The UN ID numbers will be shown below the “E” in the circle.

A summary of the labeling requirements for radioactive material packages is shown in Table 9-2 on the following page.

## Table 9-2. Summary of Labeling Requirements for Radioactive Material Packages

### Labeling for Class 7 (Radioactive) Material Packages (49 CFR 172, Subpart E)

**NOTE**: The IAEA, ICAO, and IMO may require additional hazard communication information for international shipments.

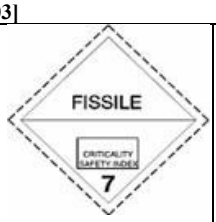
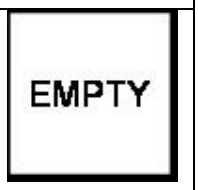
**Placement of RADIOACTIVE Labels**

Labeling must be (1) printed or affixed to the package (not the bottom), (2) placed near the proper shipping name marking, (3) in contrast with its background, (4) unobscured by markings or attachments, (5) within the color, design, and size tolerance, and (6) representative of the hazardous material contents of the package. In addition, multiple labels must be within 150 mm (6 inches) of each other. [172.406, 172.407]

Packages of radioactive material must have two RADIOACTIVE labels affixed to opposite sides. When FISSILE labels are required, two labels must be used. [172.402(d)(2)]

For radioactive material, the label must be for the highest category required for any of the two determining conditions (i.e., TI and maximum radiation level on the package surface). The RADIOACTIVE WHITE-I label is the lowest category, and the RADIOACTIVE YELLOW-III label is the highest category.

**Determination of Required Labels [172.403]**

| | | |  |  |
|---|---|---|---|---|
| WHITE I | YELLOW II | YELLOW III | FISSILE | EMPTY |
| Surface Radiation Level<br>≤0.005 mSv/hr<br>(0.5 mrem/hr)<br><br>Transport Index<br>TI = 0<br>(If the measured TI is ≤0.05, the value may be considered to be 0.) | Surface Radiation Level<br>>0.005 mSv/hr<br>(0.5 mrem/hr),<br>but ≤0.5 mSv/hr<br>(50 mrem/hr)<br><br>Transport Index<br>TI>0 but ≤1 | Surface Radiation Level<br>>0.5 mSv/hr (50 mrem/hr),<br>but ≤2 mSv/hr<br>(200 mrem/hr)<br><br>**NOTE**: If the package exceeds 200 mrem/hr, then it must be shipped exclusive use in a closed transport vehicle. [173.441(b)]<br><br>Transport Index<br>TI >1 and if >10 exclusive use | Each package containing fissile material (other than fissile excepted) must be labeled with two FISSILE labels affixed adjacent to the RADIOACTIVE labels. [172.402(d)(2)] | The EMPTY label is required for shipment of empty Class 7 packages made pursuant to Section 173.428. |

**Contents on RADIOACTIVE and FISSILE Labels**

The RADIOACTIVE and FISSILE labels must contain the following information entered using a durable, weather-resistant means:

1. The names of the radionuclides in the package. [172.403(g)(1) and 173.433(g)]
2. The activity in the package expressed in SI units (e.g., Bq, TBq). The weight in g or kg of fissile radionuclides may be inserted instead of the activity units. [172.403(g)]
3. The TI is entered *only* on RADIOACTIVE YELLOW-II and RADIOACTIVE YELLOW-III labels. [172.403(g)]
4. The CSI is entered *only* on the FISSILE label. [172.403(e)]

**Special Considerations/Exceptions for Labeling**

- Any package containing a highway route-controlled quantity must be labeled with the RADIOACTIVE YELLOW-III label. [172.403(c)]
- For material meeting the definition of another hazard class, labels for each secondary hazard class must be affixed to the package. The subsidiary label *may* not be required on opposite sides, but it must display the hazard class or division number in the lower corner. [172.402]
- When one or more packages of Class 7 (radioactive) material are placed in an overpack, the overpack must be labeled in accordance with Section 172.403(h).
- A label is not required on a package of LSA material or SCO when transported under Section 173.427(a)(6)(vi).
- Excepted packages are excepted from labeling. However, if the excepted quantity meets the definition for another hazard, it is reclassed for that hazard. Hazard communication requirements for the other class are required. [173.423]
- Empty packages (UN 2908) must have the EMPTY label in accordance with Section 173.428.
- The CARGO AIRCRAFT ONLY label is required for radioactive material packages that are prohibited from being shipped by passenger aircraft. [172.402(c)]

## 9.8 REVIEW QUESTION SET 12

1. Referring only to Column 6 of the HMT, indicate what label, if any, is specified for the following materials:

   **Phenacyl Bromide**
   - **6.1**
   - 3
   - 8

   **Consumer commodity**
   - 3
   - 8
   - **None**

   **Petroleum gases, liquefied**
   - **2.1**
   - 3
   - 5.1

   **Black powder (gunpowder)**
   - 1.4S
   - 1.3
   - **1.1D**

2. A package of Class 3 (flammable liquid), Packing Group I, material that has a subsidiary hazard meeting the definition of a Class 6.1 (poison liquid), Packing Group II, requires only a FLAMMABLE LIQUID label.

   a. True
   **b. False 172.402**

3. A 4-liter package of Class 7 (radioactive) material that has a subsidiary hazard of Class 3 (flammable liquid) is required to have both a RADIOACTIVE label and a FLAMMABLE LIQUID label.

   **a. True 172.402(d)**
   b. False

4. An overpack containing packages of different hazard classes would be labeled:

   a. With only the label for the highest hazard class.
   b. With the label for the package containing the greatest amount of material.
   **c. With labels required for each hazard class in the overpack. 172.404**
   d. Only when shipped by air or water.

5. Generally, labels must be on the same surface of the package as the marked shipping name.

   **a. True 172.406**
   b. False

6. What label is required on a package of radioactive material with a reading of 0.4 mrem/hr (0.004 mSv/hr) on the surface of the package? The reading at 1 meter is <0.05 mrem/hr, and the radioactive material is a nonfissile material.

   **RADIOACTIVE WHITE-I**

7. What label is required on a package of radioactive material with a reading of 3.2 mrem/hr (0.032 mSv/hr) on the surface of the package? The reading at 1 meter is 0.3 mrem/hr (0.003 mSv/hr), and the radioactive material is a nonfissile material.

   RADIOACTIVE YELLOW-II

8. What label is required on a package of radioactive material with a reading of 8.2 mrem/hr (0.082 mSv/hr) on the surface of the package? The reading at 1 meter is 1.3 mrem/hr (0.013 mSv/hr), and the radioactive material is a nonfissile material.

   RADIOACTIVE YELLOW-III

9. What label is required on a package containing a highway route-controlled quantity of a fissile material with a dose rate of 0.7 mrem/hr at the surface of the package, and readings at 1 meter are indistinguishable from background?

   RADIOACTIVE YELLOW-III and FISSILE

## 9.9 PLACARDING

As a general rule, each transport vehicle and freight container containing hazardous material must be placarded on each end and on each side with the placards as specified in Tables 1 and 2 in Section 172.504(e). Note that the placarding tables list the hazardous materials by category of material, which includes the hazard class and additional descriptions. For example, Class 6 (poisons) appears in both Table 1 and Table 2, the distinction being the packing group and whether or not the material meets the inhalation hazard criteria. Placards must only be used for materials that are hazardous materials, and they must represent the hazard of the materials being transported.

A vehicle transporting packages of limited quantity hazardous materials (no matter how much is aboard) does not require placards. In other words, the shipper could have 40,000 lb of acetone (packaged as a limited quantity) on a semitrailer, but no placards would be required or necessary. Notice that there is a condition to this exception. The shipping papers must contain an entry identifying the limited quantity shipment. Another example of an exception would be a vehicle containing 40,000 lb of material classed as ORM-D. This vehicle would also not be subject to placarding. (See Section 172.500(b).)

Table 1 of Section 172.504 lists the hazard classes that require placarding in any quantity. Note the footnote for radioactive material.

Once a transport vehicle or freight container contains 454 kg (1001 lb) or more gross aggregate weight of Table 2 items, each category of hazard must be represented by a placard for that hazard class or the DANGEROUS placard, when appropriate.

**Table 1 - Placard Any Quantity**

Note exceptions in parentheses for Divisions 5.2, 6.1 and Class 7.

TABLE 1

| Category of material (Hazard class or division number and additional description, as appropriate) | Placard name | Placard design section reference (§) |
|---|---|---|
| 1.1 | EXPLOSIVES 1.1 | 172.522 |
| 1.2 | EXPLOSIVES 1.2 | 172.522 |
| 1.3 | EXPLOSIVES 1.3 | 172.522 |
| 2.3 | POISON GAS | 172.540 |
| 4.3 | DANGEROUS WHEN WET | 172.548 |
| 5.2 (Organic peroxide, Type B, liquid *or* solid, temperature controlled). | ORGANIC PEROXIDE | 172.552 |
| 6.1 (inhalation hazard, Zone A or B) | POISON INHALATION HAZARD | 172.555 |
| 7 (Radioactive Yellow III label only) | RADIOACTIVE [1] | 172.556 |

[1] RADIOACTIVE placard also required for exclusive use shipments of low specific activity material and surface contaminated objects transported in accordance with § 173.427(a) of this subchapter.

5.2 (Organic peroxide, Type B, liquid *or* solid, temperature controlled).
6.1 (inhalation hazard, Zone A or B).....
7 (Radioactive Yellow III label only).....

**Table 2 - Aggregate Gross Weight**

- 454 kg (1,001 lbs.) or more must be placarded
- Less than 454 kg (1,001 lbs.) may be placarded, but is not required

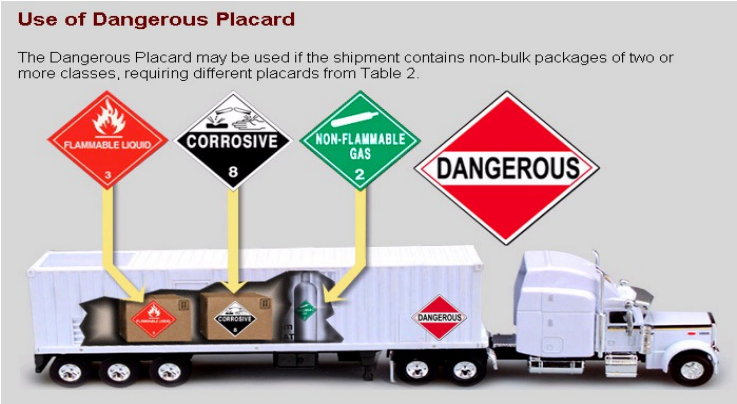
TABLE 2

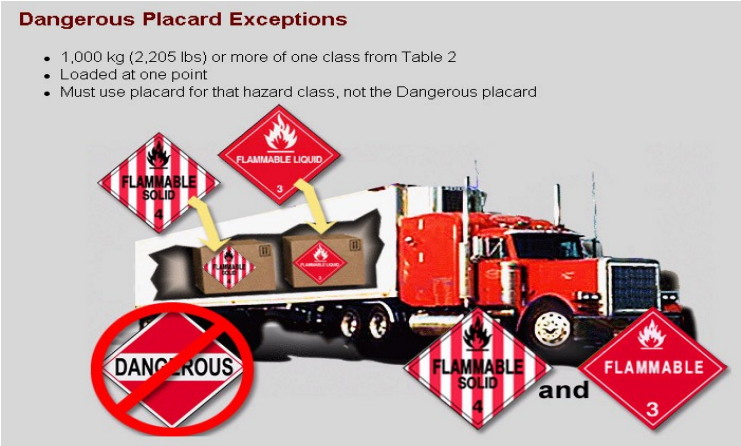
| Category of material (Hazard class or division number and additional description, as appropriate) | Placard name | Placard design section reference (§) |
|---|---|---|
| 1.4 | EXPLOSIVES 1.4 | 172.523 |
| 1.5 | EXPLOSIVES 1.5 | 172.524 |
| 1.6 | EXPLOSIVES 1.6 | 172.525 |
| 2.1 | FLAMMABLE GAS | 172.532 |
| 2.2 | NON-FLAMMABLE GAS | 172.528 |
| 3 | FLAMMABLE | 172.542 |
| Combustible liquid | COMBUSTIBLE | 172.544 |
| 4.1 | FLAMMABLE SOLID | 172.546 |
| 4.2 | SPONTANEOUSLY COMBUSTIBLE | 172.547 |
| 5.1 | OXIDIZER | 172.550 |
| 5.2 (Other than organic peroxide, Type B, liquid or solid, temperature controlled). | ORGANIC PEROXIDE | 172.552 |
| 6.1 (PG I or II, other than Zone A or B inhalation haz- | POISON | 172.554 |
| | AWAY FROM F | |

1.4 EXPLOSIVES * 1

Do not combine Table 1 and Table 2 items when determining placarding. Note that the first part of the sentence in the paragraph lists when the 1001-lb exception does not apply. Also, additional exceptions to placarding are listed in Section 172.504(f).

The DANGEROUS placard may be used in place of the placards specified in Table 2 under certain conditions. (Use of the word *may* means this substitution is permissible and not required.) Notice also that this provision applies only to nonbulk packaging <u>and</u> there must be two or more categories of hazardous materials involved.




Any time 1000 kg (2205 lb) of material or more than one category of hazardous materials from Table 2 are loaded at one loading point, which could be at a shipper's dock or a carrier's terminal, the placard specified in the table for that category must be used.

## Providing and Affixing Placards – Highway

The shipper must provide the required placards for the shipment unless the vehicle is already placarded. Regardless of whether the shipper must provide the placards or not for a particular shipment, the carrier must ensure the transport vehicle is properly placarded before transportation begins. **NOTE: By rail, placards must be affixed by the shipper.**

The required placarding on the front of a motor vehicle may be on the front of a truck-tractor instead of or in addition to the placarding on the front of the motor vehicle (semitrailer) to which the truck-tractor is attached. Generally, placards must be:

- Securely affixed.
- Placed clear of ladders, pipes, tarps, etc.
- Located so that water and dirt from the wheels are not directed on them.
- Kept at least 3 inches from advertising and markings.
- Displayed so that the words read horizontally.
- Maintained so that the visibility, color, and legibility are not substantially reduced.

### Placarding For Subsidiary Hazards

Section 172.505 specifies when placards are required in addition to the placards required by the tables in Section 172.504. For example, a vehicle transporting a material described on the shipping papers as Class 3 and PIH must be placarded with the words *Poison Inhalation Hazard* in addition to the placard for its primary hazard category. In this example, the vehicle would have both the FLAMMABLE and PIH placards. Since the 454 kg (1001 lb) exception in Section 172.504(c) does not apply to material subject to Section 172.505, the multiple placarding example mentioned here would apply regardless of the quantity of material on the vehicle.

### Placarding Freight Containers

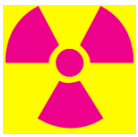
There is a difference between placarding the freight container and placarding the vehicle transporting the freight container. See Section 172.512 and Figure 9-3 for more information on placarding freight containers.

**Freight Containers**

When placards are required, placard both ends and both sides of freight containers and unit load devices (ULD) of 18 cubic meters (640 cubic feet) capacity or more. When the aggregate gross weight of a Table 2 material in a freight container or unit load device is less than 454 kg (1,001lbs), placards are not required for the motor vehicles transporting the freight container or ULD.

**Figure 9-3. Placarding freight containers**

## 9.10 PLACARDING REQUIREMENTS FOR RADIOACTIVE MATERIAL



Placarding information for radioactive material shipments is located in Sections 172.504–507. A summary of the placarding requirements for Class 7 shipments is shown in Table 9-3 on page 9-18. Placarding is required for conveyances carrying radioactive material under the following conditions:

(1) There is at least one package bearing the RADIOACTIVE YELLOW-III label.

(2) Exclusive use LSA/SCO shipments (except for unconcentrated U or Th ore).

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

(3) Highway route-controlled quantity shipments (square-background placard by highway or regular placard by rail).

In addition, Section 172.505(b) requires that shipments containing 454 kg (1001 lb) or more of $UF_6$ must display the CORROSIVE placard in addition to any required RADIOACTIVE placard.

*NOTE: In the case of foreign shipments coming into the United States, the placard may take the format of an enlarged RADIOACTIVE label. This may be seen on freight containers and unit load devices.*

**Table 9-3. Placarding Requirements for Radioactive Material Shipments**

## Placarding for Class 7 (Radioactive) Material
## (49 CFR Part 172, Subpart F)

**NOTE**: The IAEA, ICAO, and IMO may require additional hazard communication information for international shipments.

### Visibility and Display of RADIOACTIVE Placards

Placards must be displayed:

- On four sides of the vehicle. [172.504(a)]
- Visible from the direction they face on each side and each end of the vehicle (i.e., four placards). [172.516(a)]
- On the front of a motor vehicle instead of, or in addition to, the front of the cargo body (i.e., five placards). [172.516(b)]
- Securely attached or affixed to the vehicle or in a holder. [172.516(c))(1)]
- Clear of appurtenances and devices (e.g., ladders, pipes, tarpaulins). [172.516(c))(2)]
- So that dirt or water is not directed to them from the wheels of the transport vehicle, as far as practicable. [172.516(c))(3)]
- At least 3 inches from any markings (such as advertisements) that may reduce the placards' effectiveness. [172.516(c))(4)]
- Upright and on-point such that the words read horizontally, left to right. [172.516(c))(5)]
- So that they are in contrast with the background or have a solid or dotted-line border that contrasts with the background. [172.516(c))(7)]

### Conditions Requiring Placarding

Placards are required:

- For any vehicle containing a package with a RADIOACTIVE YELLOW-III label. [172.504(e), Table 1]
- For shipments of LSA or SCO consigned as exclusive use. [173.427(a)(6)(v)]
- For a highway route-controlled quantity of radioactive material, and when it is transported by highway, it must be displayed on a square background. [172.507 and 172.527] Highway route-controlled quantities by other modes require the standard RADIOACTIVE placard.

### RADIOACTIVE Placards

| | | |
|---|---|---|
| | | |
| DOMESTIC | INTERNATIONAL | HIGHWAY ROUTE-CONTROLLED QUANTITY |

### Special Considerations/Exceptions for Placarding

- Domestically, substitution of the UN ID number for the word *Radioactive* on the placard is prohibited for Class 7 material. [172.503] However, some import shipments may have this substitution in accordance with international regulations. [171.12]
- If placarding for more than one hazard class, both placards must display the hazard class number. [172.519(b)(4)]
- For $UF_6$ shipments of ≥454 kg (1001 lb) gross weight, the requirement is for both RADIOACTIVE and CORROSIVE (Class 8) placards on each side and each end. [172.505(b)]
- For shipments of radiography cameras in convenience overpacks, if the overpack does not require a RADIOACTIVE YELLOW-III label, then vehicle placarding is not required (regardless of the label that must be placed on the camera). [172.403(h)(5)]

## 9.11 REVIEW QUESTION SET 13

1. A truck contains 20,000 lb (9090 kg) of ORM-D material, 20,000 lb (9090 kg) of combustible liquid in 55-gallon drums (209 liters), and 50 lb (23 kg) of radioactive material with a RADIOACTIVE YELLOW-II label. How must this truck be placarded?

    a. RADIOACTIVE placard
    b. COMBUSTIBLE placard
    c. Both a and b above
    **d. No placard 172.500(b)(6)**

2. A truck transporting 500 lb (227 kg) of Division 2.3 (poison gas) and 500 lb (227 kg) of Class 8 (corrosive) is not required to have any placards.

    a. True
    **b. False 2.3 Table 1; 8 Table 2**

3. A truck transporting packages with Class 7 (radioactive) material with RADIOACTIVE YELLOW-III labels and packages of Division 1.3 (explosives) material may be placarded with the DANGEROUS placard.

    a. True
    **b. False Table 1 Material**

4. Six thousand lb (2727 kg) of Class 8 (corrosive) material and 8000 lb (3636 kg) of Class 3 (flammable liquid) material are loaded into a truck at one loading facility. What placards apply?

    a. CORROSIVE
    b. FLAMMABLE
    c. DANGEROUS
    **d. CORROSIVE and FLAMMABLE 172.504(b); >1000 kg from each facility**

5. The 454 kg (1001 lb) exception in Section 172.504(c) does not apply to:

    a. Cargo tanks
    b. Portable tanks
    c. Tank cars
    d. Transportation by air and vessel
    **e. All the above 172.504(c)**

6. What placard is required on a motor vehicle containing one radioactive material package requiring no RADIOACTIVE label?

    **None**

7. What placard is required on a motor vehicle containing one radioactive material package requiring a RADIOACTIVE WHITE-I label?

    **None**

8. What placard is required on a motor vehicle containing one radioactive material package requiring a RADIOACTIVE YELLOW-II label?

    **None**

9. What placard is required on a motor vehicle containing one radioactive material package requiring a RADIOACTIVE YELLOW-III label?

   RADIOACTIVE

10. What placard is required when transporting highway route-controlled quantities of radioactive material:

    - By highway? RADIOACTIVE – Square Background
    - By rail? RADIOACTIVE – Square-on-Point

11. What placard is required on motor vehicles transporting exclusive use shipments of LSA radioactive material (other than unconcentrated U or Th ores)?

    RADIOACTIVE

12. Under what circumstances must a motor vehicle be placarded with a RADIOACTIVE placard?

    RADIOACTIVE YELLOW-III Label

    Exclusive Use LSA/SCO under Section 173.427(b)(4), (5), or (c)

    Highway Route-Controlled Quantities

13. What placards are required for a $UF_6$ shipment:

    - Offered as an exclusive use, LSA shipment?

      RADIOACTIVE and CORROSIVE 173.427(a)(6)(v); 172.505(b)

    - Offered as a fissile shipment?

      Placarding will be based on labeling

## 9.12 SHIPPING PAPERS

Except for the Hazardous Waste Manifest, there is no specific shipping document required by the HMR. Shippers may use whatever form or shipping document that appropriately fits their operation or the papers may be mandated by another regulation. Shipping documentation for the following shipment types has a prescribed format; otherwise, hazardous materials generally move on a standard Bill of Lading.

- Air shipments made under IATA (Shipper's Declaration).
- Water shipments made under the IMDG Code (Multimodal Dangerous Goods Form).
- Radioactive waste shipped for disposal (Low-Level Waste Manifest).
- Hazardous waste shipped for treatment or disposal (Uniform Hazardous Waste Manifest).
- PCBs shipped for disposal (Uniform Hazardous Waste Manifest).

However, each document will have the same DOT-required entries for a hazardous material shipping description.

Unless excepted by Section 172.200(b), the shipping paper entries must meet the following:

- Contain the basic description of the hazardous material being shipped as required by Sections 172.202(a)(1), (2), (3), and (4).
- Have the basic description appear in the same sequence as stated in Sections 172.202(a)(1), (2), (3), and (4).
- Contain any applicable additional description requirements stated in Section 172.203.
- Be prepared and placed on the shipping papers in accordance with the requirements of Section 172.201(a)–(d).
- Be dated and retained in accordance with Section 172.201(e).

In general, hazardous material entries on shipping papers are not required for material identified by the letters "A" or "W" in Column 1 of the HMT when transported by highway, unless they are offered or intended for transport by air or water. If these materials identified by "A" or "W" are offered or intended for transport by air or water, then the shipping paper requirements apply during the highway transport to the airport or to the dock for transport by water. Shipments of ORM-D by air must also have specific shipping paper entries. Shipments of hazardous substances and hazardous waste are subject to specific shipping paper requirements for all modes.

### Emergency Information

The shipping papers offered by the shipper and the shipping papers carried by the carrier must contain an emergency telephone number or "emergency contact" in accordance with Sections 172.201(d) and 172.604. This number may be the number of the shipper or a person "knowledgeable" about the material in question. CHEMTREC or other similar organizations may be utilized, provided prior arrangements have been made, the particular organization agrees to assume the responsibility, and only one telephone call has to be made to reach a knowledgeable person.

Another regulation pertaining to emergency response is the requirement to carry information that "can be used in the mitigation of an accident." (See Section 172.602.) This information may be in the form of a Material Safety Data Sheet, other emergency response information (such as the *Emergency Response Guidebook*), or other similar emergency response guidance manuals.

This additional emergency response information must be either (a) presented on the shipping papers or (b) be on a separate document carried in addition to the shipping papers and maintained by the carrier in the same manner as the shipping papers. This information and the telephone number requirement apply to shippers, carriers, and facilities where hazardous materials are stored or transferred incidental to transportation. (See Section 172.600(a).)

### Basic Description

The hazardous material shipping description can be broken down into the following parts:

- The UN ID number as prescribed in the HMT, Column 4, Section 172.202(a)(1).
- The proper shipping name as listed in the HMT, Column 2, Section 172.202(a)(2).
- The hazard class or division as prescribed in the HMT, Column 3, Section 172.202(a)(3).
- The packing group in Roman numerals as listed in the HMT, Column 5, Section 172.202(a)(4).
- The total quantity of material covered by the basic description, with the unit of measurement entered either before or after or both before and after the required description in accordance with Sections 172.202(a)(5) and (6).
- The number and type of packages must be indicated (e.g., 12 drums or 12 1A2 drums) in accordance with Section 172.202(a)(7).

*NOTE: The entries for the first three bullets above are known as the basic description and must appear in that sequence. See Figure 9-4 below. Section 172.202(b) allows for the basic description to be written with the UN ID number first. For the example below, the basic description would be "UN 1263, Paint, 3, Packing Group II, 25 kg."* This sequence is mandatory on January 1, 2008, under HM-215I, which was published as a final rule on December 29, 2006. However, except for shipments made under the ICAO/IATA regulations or the IMDG Code, the revised Section 171.14(e) permissively allows the old sequence to be used until January 1, 2013.

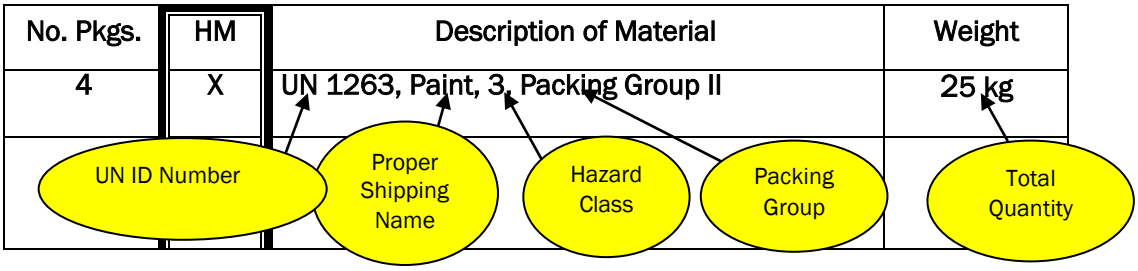



**Figure 9-4. Basic description on a shipping paper derived from information in the HMT**

Entries on shipping documents prepared under the ICAO/IATA and the IMDG Code must have the basic description in the following sequence: UN ID number, proper shipping name, hazard class or division, and packing group. In addition, the net quantity of hazardous material per package must be shown on the shipper's declaration for air shipments.

### Additional Description Requirements

In cases where an additional description requirement is identified in Section 172.203, the additional information is entered in association with the basic description. The additional information can appear in any order. Each paragraph in Section 172.203 states what must be entered as the additional descriptive information and where it must appear on the shipping papers. *NOTE: In some cases, there will be no additional description requirements.*

For shipments where no additional description is required by Section 172.203, the shipping description is complete after entering the basic description required by Section 172.202(a) and the emergency response telephone number required by Section 172.201(d).

Additional entries are required for:

- DOT special permits.
- Limited quantity.
- Hazardous substances.
- Empty packaging.
- Technical names for generic entries.
- Marine pollutants.
- Poison or toxic material.
- Inhalation hazard.
- Air, rail, and water shipment.
- Radioactive material.

| No. of Units | HM | Shipping Description | Total Quantity |
|---|---|---|---|
| 1 Carton | | UN 1207, Hexaldehyde, 3, Packing Group III | 4 liters |
| 1 Drum | RQ | UN 1617, Lead arsenates, 6.1, Packing Group II | 10 kg |
| 3 Drums | | UN 3082, Environmental Hazardous Substances, Liquid, n.o.s., 9, Packing Group III, RQ (Amitrole) | 454 kg |
| 1 Box | | UN 1760, Corrosive Liquids, n.o.s., (sulfuric acid) 8, Packing Group III | 30 liters |
| 1 Box | | UN 1100, Allyl Chloride, 3, Packing Group I, Toxic | 50 kg |
| 2 Drums | | UN 1098, Allyl alcohol, 6.1, Packing Group I, Poison Inhalation Hazard Zone B | 420 kg |

### Empty Packaging [172.203(e)]

Generally, an empty package containing residue must be offered for transport in the same manner as when it contained a greater quantity. Certain regulatory exceptions are provided for empty packaging in Section 173.29. Placarding exceptions are provided in Sections 173.29(c) and (h). Section 172.203(e) provides for the words *Residue: Last Contained **** to be entered in association with the basic description of the hazardous material last contained in the packaging.

### Marine Pollutants [172.203(l)]

When the basic description of a marine pollutant does not identify the component that makes the material a marine pollutant, the name of the component(s) must appear in parentheses in association with the basic description. The words *Marine Pollutant* must also be entered in association with the basic description.

### Inhalation Hazard [172.203(m)]

For a material meeting the criteria to be poisonous or toxic by inhalation, the words *Poison–Inhalation Hazard* or *Toxic–Inhalation Hazard* and the appropriate hazard zone must be entered on the shipping paper immediately following the shipping description. The hazard zones consist of Zone A, B, C, or D for gases and Zone A or B for liquids.

### Shipper's Certification

The shipping papers prepared by the shipper and offered to the carrier with the shipment must bear a signed shipper's certification prepared in accordance with Sections 172.204(a) or (c). The following statement from 49 CFR 172.204(a)(1) (or an alternate statement listed in Section 172.204(a)(2)) must be used for all hazardous material 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 the shipping paper in place of the above statement:

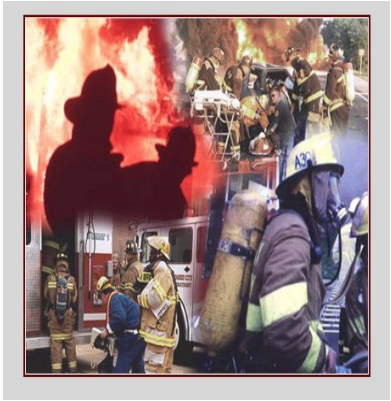
"I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packaged, marked, and labeled, and in proper condition for carriage by air according to the applicable national governmental regulations."

The requirements and limitations for transporting radioactive material aboard aircraft are prescribed in Sections 175.700 through 175.705. The following statement, with the deletion marking, is required for all hazardous materials shipments by air:

"I declare that all the applicable air transport requirements have been met."

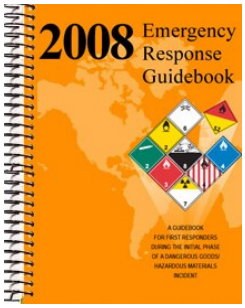
## 9.13 EMERGENCY RESPONSE INFORMATION

Title 49 CFR Part 172, Subpart G, Section 172.600, requires shippers to provide emergency response information on hazardous material shipments. The regulation applies to any shipment of a hazardous material that is required to have shipping papers. Shipments of excepted radioactive material packages (packages containing limited quantities, instruments, or articles or empty packaging) are excepted from the shipping paper requirements and, therefore, are not subject to the emergency response information requirements.



At a minimum, the emergency response information must provide:

1. Basic description and technical name of the hazardous material.
2. Immediate hazards to health.
3. Immediate precautions to be taken in the event of an accident or incident.
4. Immediate methods for handling fires.
5. Immediate methods for handling spills or leaks in the absence of fire.
6. Preliminary first aid measures.




This information must be on the shipping papers or an associated document, kept in the vehicle, and maintained at all locations where the shipment is handled. This required information is very similar to the information in the *Emergency Response Guidebook*. In many cases, shippers satisfy this requirement by attaching to their shipping papers an appropriate page from the *Emergency Response Guidebook*.

The DOT, in partnership with Canada and Mexico, developed and distributed the *Emergency Response Guidebook* with the intent that a copy be placed in every emergency services vehicle in North America. First responders to a hazardous material accident use the *Emergency*

*Response Guidebook* as a means of obtaining initial information on the identification and hazards of the specific material and to assist in decisionmaking on the actions to be taken.

The four-digit UN ID number assigned to each DOT proper shipping name is cross-referenced to a three-digit guide number in the *Emergency Response Guidebook*. For Class 7, radioactive material, the *Emergency Response Guidebook* contains guide numbers that correlate to all DOT proper shipping names for radioactive material.

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 *Emergency Response Guidebook*, 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 Section 172.602(a)(1)–(7) by preparing statements that are appropriate to the product being shipped.

Shippers are required to provide an emergency response telephone number that must be monitored on a 24-hour basis while the shipment is in transit. The number must be of a person or entity that is knowledgeable of the mitigation information or has immediate access to such a person. The number may be of an agency that is capable of providing the information and has agreed to do so.

## 9.14 HAZARDOUS WASTE MANIFEST

Section 172.205 addresses use of the Hazardous Waste Manifest for hazardous waste shipments. The specific requirements for completion of the manifest are found in 40 CFR 262. The EPA allows for electronic submission of manifests; however, that is not in compliance with the DOT requirement to have the shipping documentation readily available during transport. Therefore, shippers may transmit the manifest electronically in addition to providing a Bill of Lading and manifest when offering the shipment.

The Uniform Hazardous Waste Manifest is also required when offering PCB shipments for transport. (See 40 CFR 761.207.) The manifest is required whenever the PCB concentration exceeds 50 ppm and the shipment is offered for commercial offsite storage or disposal. The manifest is a part of the EPA's cradle-to-grave waste tracking. The manifest contains many requirements unique to the EPA; however, it interfaces with the DOT by requiring that the document show a DOT shipping description. Specific instructions for completing the manifest are provided in 40 CFR 262. Additional information about the manifesting system is available from the EPA at http://www.epa.gov/epaoswer/hazwaste/gener/manifest/registry/index.htm.

## 9.15 REVIEW QUESTION SET 14

1. Additional information, not required by 49 CFR, may be entered on the shipping paper if it is not inconsistent with the required description and follows the required entries.

    - **True 172.201(a)(4)**
    - False

2. Which of the following is a proper shipping description for a 1-quart package of oleum being shipped by highway?

    - Class 8, Oleum, UN 1831, I, 1 quart.
    - Oleum, Class 8, UN 1831, I, 1 quart.
    - **Sulfuric acid, fuming, 8, UN 1831, I, 1 quart.**
    - None of the above.

3. In addition to the basic description required by Section 172.202, additional description requirements (Section 172.203) would not be required for which of the following?

    - **Hazardous material package offered for air transportation and permitted to be transported aboard passenger aircraft.**
    - A shipment of hazardous materials defined as "limited quantities" by 49 CFR 100-177.
    - A shipment of radioactive material.
    - A shipment of a hazardous material shipped as "Flammable, liquid, n.o.s."

4. Who must ensure that the emergency response telephone number is provided?

    - Carrier
    - **Shipper**
    - CHEMTREC

5. Emergency response information is not required on a shipment that does not require shipping papers.

    - **True 172.600(d)**
    - False

6. The emergency response information document must be:

    - In the trailer with the material being transported.
    - **Immediately available.**
    - Sent to the local fire department.

7. The term *emergency response information* means information that may be used in the mitigation of a hazardous material incident.

    - **True 172.602(a)**
    - False

## 9.16 REVIEW QUESTION SET 15

1. A mixture of PCBs greater than 50 ppm, friable white asbestos (chrysolite), and mercury in 100 steel drums with a gross weight of 170 lb (77.3 kg) each. The material meets the EPA characteristic of toxicity (D009). The PCBs in each 55-gallon 1A2 drum weigh 10 lb. The mercury is dispersed throughout the material. The weight of the mercury is >3% of the total weight of the material and has failed the Toxic Characteristic Leaching Process Test. There is approximately 2 lb of asbestos in each drum. The material does not meet the DOT Class 1–8 definitions. The total weight of the material is 130 lb (59 kg). The quantity of all the constituents is known by testing and listed above. The mercury consists of elemental mercury only. This is a domestic shipment by an exclusive use motor carrier at truck load rates. The emergency response number is 865-481-4808.

| 9a HM | 9b. USDOT Description [Including Proper Shipping Name, Hazard Class, ID Number and Packing Group (if any)] | 10. Containers | | 11. Total Quantity | 12. Unit Wt/Vol. | 13. Waste Codes | | |
|---|---|---|---|---|---|---|---|---|
| | | No. | Type | | | | | |
| RQ | NA3077, Hazardous Waste, Solid, n.o.s., 9, III (PCBs, Asbestos, D009) | 100 | DM | 7730 | K | D009 | | |
| | OR | | | | | | | |
| RQ | UN3077, Waste Environmentally Hazardous Substances, n.o.s., 9, III (PCBs, Asbestos, D009)<br><br>Emergency Contact: 865-481-4808 | | | | | | | |
| 14. Special Handling Instructions and Additional Information<br>40 CFR 761.207 INFO | | | | | | | | |

- What markings are required? RQ, Proper Shipping Name, UN ID number (PCBs, Asbestos, D009), Names/Addresses, RCRA Waste Marking, TSCA PCB Marking, Part 178 Packaging Marking
- What labels are required? Class 9
- What placards are required? None

2. Four plastic drums of beryllium powder (diameter less than 100 micrometers). The gross weight of the shipment is 890 lb (404.5 kg). The net weight of the material is 560 lb (254.5 kg) distributed equally in each 55-gallon 1H2 plastic drum (140 lb per container). The shipment is by exclusive use motor vehicle. The emergency response number is 865-481-4808. This is a domestic shipment.

| NO. PKGS | HM | DESCRIPTION OF MATERIAL | WEIGHT |
|---|---|---|---|
| 4 Drums | RQ | UN 1567, Beryllium Powder, 6.1 (4.1), II<br><br>Emergency Contact: 865-481-4808 | 890 lb |

- What markings are required? RQ Beryllium Powder, UN 1567, Names/Addresses, Part 178 Package Marking
- What labels are required? 6.1, 4.1
- What placards are required? None

3. One fiberboard package containing 1200 mL of a liquid mixture of soil samples immersed in hexane being transported to North Carolina for analysis. The package weight is 20 lb (9.1 kg). The emergency response number is 865-481-4808. The shipment is prepared and offered by truck transport to an airport. The material is to be packaged in combination packaging to satisfy the requirements of the air carrier. The shipment is to be made by air using the IATA *Dangerous Goods Regulations*, and it will be made by cargo aircraft. The inner packaging is glass. The receiver desires not to receive the material shipped as a limited quantity.

| | | | | | | |
|---|---|---|---|---|---|---|
| Shipper | | | | Air Waybill No<br>Page of pages<br>Shipper's Reference Number | | |
| Consignee | | | | | | |
| This shipment is within the limitations prescribed for: (delete nonapplicable) | | Airport of Departure | | WARNING<br>Failure to comply in all respects with the applicable *Dangerous Goods Regulations* may be in breach of the applicable law, subject to legal penalties. | | |
| ~~PASSENGER AND CARGO AIRCRAFT~~ | CARGO AIRCRAFT ONLY | | | | | |
| Airport of Destination: | | | Shipment type: (delete nonapplicable)<br>NONRADIOACTIVE / ~~RADIOACTIVE~~ | | | |
| NATURE AND QUANTITY OF DANGEROUS GOODS | | | | | | |
| UN or ID no. | Proper Shipping Name | Class or Division (Subsidiary Risk) | Packing Group | Quantity and type of packing | Packing Inst. | Authorization |
| UN 1208 | HEXANES MIXTURE, SAMPLE | 3 | II | (1) 4G FIBREBOARD BOX x 1200 mL | 307 | |
| Additional Handling Information EMERGENCY CONTACT: 865-481-4808 | | | | | | |

- What markings are required? Proper Shipping Name, UN ID number, Part 178 Package Marking, Orientation Arrows, Names/Addresses
- What labels are required? FLAMMABLE label
- What placards are required? None

4. Four metal bulk containers (less than 1000-gallon capacity) by motor vehicle weighing a gross total of 700 lb (318.2 kg) each. The packages contain manufactured items exceeding 50 ppm of PCBs. There are approximately 20 lb of PCBs in each container. The shipment is an environmental project being performed by DOE. The emergency response number is 865-481-4808.

| 9a. HM | 9b. US DOT Description [Including Proper Shipping Name, Hazard Class, ID Number and Packing Group (if any)] | 10. Containers | | 11. Total Quantity | 12. Unit Wt/Vol. | 13. Waste Codes | | |
|---|---|---|---|---|---|---|---|---|
| | | No. | Type | | | | | |
| RQ | UN 2315, Polychlorinated Biphenyls, Solid, Mixture, 9, Packing Group III<br><br>Emergency Contact: 865-481-4808 | 4 | DM | 1273 | K | | | |
| 14. Special Handling Instructions and Additional Information<br>40 CFR 761.207 INFO | | | | | | | | |

- What markings are required? RQ Proper Shipping Name, UN ID number, Container and TSCA PCB Marking, 2315 Orange Panel
- What labels are required? None
- What placards are required? None

5. One dump-trailer load of dirt being transported by motor vehicle. The activity is an environmental restoration project. The dirt contains 9.25 Bq/g (250 picocuries/g) of $^{137}Cs$. The net weight of the dirt is 30,000 lb (13,620 kg). The emergency response number is 865-481-4808.

| NO. PKGS | HM | DESCRIPTION OF MATERIAL | WEIGHT |
|---|---|---|---|
| 1 TRUCK | | DIRT | 30,000 LBS |

- What markings are required?
- What labels are required?
- What placards are required?

$^{137}Cs$ exempt concentration: 10 Bq/g exempt activity: 10,000 Bq

Not Class 7

RQ = 0.037 TBq

Have: 10 E-12 TBq/g (13,620 E3 g) = 0.0001 TBq not RQ

6. Five gallons of benzene (36.6 lb), 1 quart of acetone (1.4 lb), and 1 quart of ethyl alcohol (1.3 lb) in individual glass and metal containers. The benzene is a toxicity characteristic waste (D018). The package (1G fiber drum) weighs 65 lb (29.5 kg). The benzene weighs approximately 35 lb. The emergency response number is 865-481-4808. The materials are discarded chemical products. This material is to be shipped as a lab pack by a contract exclusive use motor vehicle. The material has been analyzed, and the contents by weight have been determined.

| 9a HM | 9b. USDOT Description [Including Proper Shipping Name, Hazard Class, ID Number and Packing Group (if any)] | 10. Containers | | 11. Total Quantity | 12. Unit Wt/Vol. | 13. Waste Codes | | |
|---|---|---|---|---|---|---|---|---|
| | | No. | Type | | | | | |
| RQ | UN 1992, Waste Flammable Liquids, Toxic, n.o.s., 3, (6.1) Packing Group II, (D018)<br><br>Emergency Contact: 865-481-4808 | 1 | DM | 65 | P | D018 | | |

- What markings are required? Names/Addresses, RQ, Proper Shipping Name, UN ID number, (D018), EPA RCRA Waste and Part 178 Packaging Marking, Orientation Arrows
- What labels are required? 3, 6.1
- What placards are required? None

## 9.17 SHIPPING DOCUMENTATION FOR RADIOACTIVE MATERIAL

In addition to the basic description required for all hazardous material shipments (proper shipping name, hazard class, and UN ID number) and the other required entries (e.g., RQ and emergency response number), the additional requirements for radioactive material are provided in Section 172.203(d). There are shipping paper exceptions for excepted packaging shipments that are not a hazardous substance or a hazardous waste.

Shipping documentation follows a prescribed format for the following shipment types; otherwise, radioactive material generally moves on a standard Bill of Lading:

- Air shipments made under the IATA (Shipper's Declaration).
- Water shipments made under the IMDG Code (Multimodal Dangerous Goods Form).
- Radioactive waste shipped for disposal (Low-Level Waste Manifest).
- Hazardous waste shipped for treatment or disposal (Uniform Hazardous Waste Manifest).
- PCBs shipped for disposal (Uniform Hazardous Waste Manifest).

Shippers have the greatest responsibility for compliance with the communication requirements of 49 CFR 172, but carriers are also subject to some of the requirements. Safe transport of radioactive material requires correct communication of the specific hazards of the material. It is an essential part of the total system for providing safe transport of radioactive materials.

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

### Basic Shipping Paper Requirements

The shipping paper description must include the following basic description:

- The UN ID number.
- The proper shipping name from Section 172.101.
- The hazard class or division. Radioactive material is Hazard Class 7.
- The quantity of the material by weight, volume, or activity, as appropriate. Note that Section 172.202(a)(5)(iii) excepts bulk packaging from this requirement.

  ***NOTE: Section 172.203(d)(3) requires the activity per package to be shown. For shipments with multiple nonbulk radioactive material packages, the total shipment activity should be shown in addition to the activity per package to meet Section 172.202(a)(5). The gross weight or volume is usually shown to establish the freight charges.***
- The number of packages and type.
- The letters *RQ* if the shipment is a hazardous substance. See Section 172.101, Appendix A, Table 2, for the RQ values of radionuclides.
- The emergency response telephone number as prescribed in Part 172, Subpart G.

The shipping papers 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.

### Additional Shipping Paper Description for Radioactive Material

Section 172.203(d) details the additional shipping paper descriptions for radioactive material, and this information, as appropriate, follows this basic description:

- The name of each radionuclide in the material as listed in Section 173.435. For mixtures of radionuclides, only the radionuclides that constitute 95% of the hazard of the mixture, as determined by the equation in Section 173.433(f), need to be listed on the shipping papers and package labels.
- A description of the physical and chemical form of the material, unless the material is a special form.
- The activity contained in each package in the shipment in appropriate SI units (Bq, TBq, etc.).
- If the package contains a highway route-controlled quantity, then those words (or the letters *HRCQ*) must also be shown with the basic description.
- The category of RADIOACTIVE label applied to each package in the shipment (e.g., a RADIOACTIVE WHITE-I label).
- The TI assigned to each package in the shipment bearing a RADIOACTIVE YELLOW-II or RADIOACTIVE YELLOW-III label.
- For a shipment of fissile material, the additional information required by Section 172.203(d)(7), i.e., the words *Fissile Excepted* or the CSI.

  ***NOTE: For a package containing a fissile nuclide with an activity content less than the definition of radioactive material, the term Fissile Excepted need not be added, since a material having an activity content less than the transport definition of radioactive material is not subject to the transportation regulations.***
- For a shipment required to be consigned as exclusive use, an indication that the shipment is consigned to be exclusive use, along with any appropriate special instructions to the carrier relative to maintenance of the exclusive use shipment controls.
- The Certificate of Approval marking required on the package must also be noted on the shipping papers if the package is (1) approved and certified by the NRC or DOE or (2) a package of foreign origin that has been revalidated by the DOT.

### Proper Shipping Names for Fissile and Fissile-Excepted Material

If the radioactive material is not fissile excepted, use the following shipping names, as appropriate:

- "Radioactive material, Type A package, fissile"
- "Radioactive material, Type B(M) package, fissile"
- "Radioactive material, Type B(U) package, fissile"

***NOTE: For fissile material shipped in a DOT Specification 6M package, the proper shipping name is "Radioactive material, Type B(U) package, fissile, UN 3328."***

When shipping a fissile-excepted material, an appropriate proper shipping name should be chosen based on the quantity, i.e., the shipping names for excepted packaging, Type A, Type B, or LSA/SCO. The words *Fissile Excepted* must be added to the shipping description.

### Documentation for Excepted Packages

Packages shipped according to the exceptions provided in Sections 173.421, 173.424, 173.426, and 173.428 for limited quantity, instruments or articles, articles manufactured from natural or

depleted U or natural Th, and empty radioactive material packaging are excepted from the detailed shipping paper description requirements.

***NOTE: Although shipping papers are not required for these excepted packages, they are not forbidden. Furthermore, in accordance with Section 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 Section 171.8.***

In addition, when air shipment of an excepted package is involved, the shipper should be aware that a prescribed statement on the Air Waybill is required by the ICAO and IATA regulations. See the Air Waybill requirements in Section 10.8.8.3 in the IATA regulations.

### Other Information and Examples of Shipping Papers Entries

As indicated above, a great deal of specific information is required on the shipping papers for radioactive material. While there is no precise prescription for the shipping paper format, the first three entries of the basic description must be in a specific order. Other descriptive information is allowed; however, it must not confuse or detract from the required description.

Entries on shipping documents prepared under the ICAO/IATA and the IMDG Code must have the basic description in the following sequence: UN ID number, proper shipping name, hazard class or division, and packing group. In addition, the net quantity of hazardous material per package must be shown on the shipper's declaration for air shipments. Section 172.204(c)(4) requires an additional certification for all radioactive material shipments, except for those in excepted packaging that are offered for transport by passenger aircraft. The shipper must certify that the contents are intended for use in or are incidental to research, medical diagnosis, or treatment.

There are a number of specific requirements for completing a shipper's declaration under the IATA regulations. (See the IATA 10.8.) Some of these requirements include the following:

- The packing group must be shown for a radioactive material with a subsidiary risk.
- The category of RADIOACTIVE label should be shown as RADIOACTIVE I-WHITE, RADIOACTIVE II-YELLOW, or RADIOACTIVE III-YELLOW, as appropriate.
- Notations must be shown for:
  - Special form approval.
  - Type B package and Type B(M) shipment approval.
  - Fissile material package design approval.
  - Special arrangement approval.
- For LSA-II, LSA-III, SCO-I, and SCO-II shipments, the total activity of the consignment must be shown as a multiple of the $A_2$ value.
- For a package with RADIOACTIVE YELLOW-II or RADIOACTIVE YELLOW-III labels, the dimensions of the package must be shown.

A summary of the shipping paper requirements for radioactive material shipments is shown in Table 9-4 on the following page.

**Table 9-4. Summary of Shipping Paper Requirements for Radioactive Material Shipments**

## Shipping Paper Requirements for Class 7 (Radioactive) Material (49 CFR Part 172, Subpart C)

NOTE: The IAEA, ICAO, and IMO may require additional hazard communication information for international shipments.

### Entries Always Required

The basic description, in sequence:

- Hazard Class, Proper Shipping Name, UN ID Number [172.202(a), (b)]
- The total quantity of the material described (mass, volume, or activity) in appropriate units (kg, liters, etc.) [172.202(a)(5)]
- The number and type of packages [172.202(a)(6)]
- The name of each radionuclide as determined by Section 173.433(g)
- The activity per package must be shown in SI units (e.g., Bq, TBq). Abbreviations are authorized. [172.203(d)(1) and (3)]
- If not a special form, a description of the chemical and physical form [172.203(d)(2)]
- For each labeled package:
  - The category of label used
  - The TI of each package with a RADIOACTIVE YELLOW-II or RADIOACTIVE YELLOW-III label [172.203(d)(5)]
- The CSI of a package with a FISSILE label [172.203(d)(6)]
- The shipper's certification (not required for private carriers) and signature [172.204]
- A 24-hour emergency response telephone number (Use of a number that requires a call back—answering machine—is not authorized.) [172.201(d) and 172.604]

### Entries Sometimes Required

#### Materials-Based Requirements

If a hazardous substance, the letters *RQ* immediately before or after the basic description. [172.203(c)(2)]

The words *Highway Route-Controlled Quantity* (or the letters *HRCQ*) entered in association with the basic description. [172.203(d)(10)]

For a package containing fissile material, the words *Fissile Excepted* if the package is excepted by Section 173.453; otherwise, the CSI for that package. [172.203(d)(6)]

If the material is considered to be a hazardous waste and the word *Waste* does not appear in the shipping name, then the word *Waste* must precede the shipping name (e.g., UN 2915, Waste Radioactive Material, Type A package, 7). [172.101(c))(9)]

Except for $^{239}$Pu and $^{241}$Pu, the weight in g or kg of fissile radionuclides may be inserted instead of the activity units. For $^{239}$Pu and $^{241}$Pu, the weight in g of fissile radionuclides may be inserted in addition to the activity units. [172.203(d)(3)]

#### Package-Based Requirements

Package identification marking for DOE- or NRC-certified packages [172.203(d)(7)]

The IAEA Certificate of Competent Authority identification number for export shipments or shipments using foreign-made packaging. (See Section 173.473.) [172.203(d)(8)]

#### Administrative-Based Requirements

Exclusive use shipments. [172.203(d)(9)]

If a DOT special permit is being used, the letters *SP-* followed by the exemption number. [172.203(a)]

Cargo aircraft only. [172.203(f)]

If a subsidiary hazard is present, the hazard class or division number. [172.202(a)(2)]

Emergency response information may be entered on the shipping papers, or it may be a separate document carried with the shipping papers. [172.602(b)]

### Special Considerations/Exceptions for Shipping Papers

Excepted packages (e.g., limited quantity [UN 2910], instruments or articles [UN 2911], manufactured articles of U and Th [UN 2909], and empty packages [UN 2908]) are excepted from shipping papers. For excepted quantities, this is only true if the excepted quantity is not a hazardous substance (RQ) or a hazardous waste. [173.422(e)]

For shipments of multiple cargo types, any hazardous material entries must appear as the first entries on the shipping papers, be designated by an "X" (or "RQ") in the Hazardous Material column, or be highlighted in a contrasting color. [172.201(a)]

Instructions for maintenance of exclusive use shipment controls for LSA material or SCO must be included with the shipping papers. [173.403 and 173.427(a)(6)(iv)]

The shipping paper retention period is two years for the shipper, and one year for the carrier (three years for both carrier and shipper for hazardous wastes). [172.201(e), 177.817(f), 175.33(b), 174.24(b), 176.24(b)]

Examples of Radioactive Material Shipping Descriptions

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

One (1) box

RQ UN 2916, Radioactive Material, Type B(U) package, 7, 22.7 kg gross
Iridium--192, Special Form, 2.2 TBq
RADIOACTIVE YELLOW-II, Transport Index 0.6
USA/9033/B(U)
In emergency, contact: 1-800-000-0000.

One (1) carton

UN 2915, Radioactive Material, Type A package, Class 7(8), 7.8 kg gross
$^{60}$Co, 0.01 GBq
liquid, cobalt in 50 mL 5% hydrochloric acid solution,
RADIOACTIVE YELLOW-III and CORROSIVE labels applied, TI = 1.8
Emergency contact: 1-800-000-0000.

One (1) box

UN 2915, Radioactive Material, Type A package, 7(5.1), 10 kg net
Thorium natural, as powdered solid thorium nitrate
48 MBq (1.3 mCi),
RADIOACTIVE YELLOW-II and 5.1 labels, TI 0.1
DOT Spec. 7A
CARGO AIRCRAFT ONLY
In emergency, contact: 1-800-000-0000.

***NOTE: Although this material is also an LSA-I, it must be packaged and shown on the shipping papers in accordance with the specific packaging requirements of Section 173.419, with air shipment limited to not more than 11.3 kg by cargo aircraft only.***

(3) drums

UN 3321 Radioactive Material, low-specific activity (LSA-II) 7, 363 kg ea.
$^{137}$Cs, $^{60}$Co and $^{90}$Sr
Solid, elemental, and inorganic salts in noncompacted solid debris and waste

| Drum No. | Activity (MBq) |
|---|---|
| 731 | 1.5 |
| 680 | 0.57 |
| 541 | 0.18 |

Total activity: 2.25 MBq
See attached Rad Waste Manifest XZ 00052
Exclusive use shipment
In emergency, contact (24-hour) 1-800-000-0000.

***NOTE: This is an example of a shipment under Section 173.427(b)(4). The material is being shipped for disposal, so a Low-Level Radioactive Waste Manifest is required. (The word waste does not appear before the basic description because the material is not an EPA RCRA hazardous waste.)***

(3) cartons

UN 2915, Radioactive Material, Type A package, 7,
ALL MATERIAL TO BE USED IN PHYSICAL CHEMISTRY RESEARCH PROJECT
Total Activity: 4.55 GBq

Carton No. 1, catalytic specimen, $^{35}$S, 2.6 GBq
solid, powdered metal oxide matrix
RADIOACTIVE WHITE-I label, 60 lb

Carton No. 2, Tagged solvent, $^{30}Cl$, 0.11 GBq
Liquid, nonflammable organic
RADIOACTIVE WHITE-I label, 50 lb

Carton No. 3, converter element, $^{59}Fe$ and $^{55}Fe$
1.1 GBq and 0.74 GBq, solid steel part
RADIOACTIVE YELLOW-III label, TI 1.6, 80 lb

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

4 cylinders — UN 2977, Radioactive Material, uranium hexafluoride, fissile, 7
Total Gross Weight: 18,795 kg
Total Activity: 2.52 GBq
Solid Uranium Hexafluoride ($UF_6$) contained in four Model 30B steel cylinders, each enclosed in a Model UX-30 protective overpack
Each cylinder contains 2277 kg of $UF_6$
5.0 % $^{235}U$ enrichment, (629 MBq)
NRC Certificate USA/9196/AF, Type A
RADIOACTIVE YELLOW-III labels, TI = 5.0/package
RADIOACTIVE and CORROSIVE placards and orange 2977 UN panel applied.
24-hour Emergency Telephone: contact 1-888-888-8888.

## 9.18 EXAMPLES OF SHIPPING DOCUMENTATION

Examples of the shipping documentation listed below are provided on the following pages.

- Straight Bill of Lading
- Air Shipper's Declaration
- IMDG Dangerous Goods Form
- Asbestos Waste Shipment Record
- Uniform Hazardous Waste Manifest
- Uniform Low-Level Radioactive Waste Manifest

## STRAIGHT BILL OF LADING SHORT FORM NOT NEGOTIABLE

CARRIER:
Carrier No: SCAC No:
Purchase / Customer Order No:

Shipper No:
Date:

Received, subject to the classifications and tariffs in effect on the date of the issue of this Bill of Lading, the property described below in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned, and destined as indicated below, which said carrier agrees to carry to its usual place of delivery. If on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed as to each carrier of all or any of said route to destination and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all Bill of Lading terms and conditions in the governing classification on the date of shipment. The shipper hereby certifies that he is familiar with all the Bill of Lading terms and conditions in the governing classification and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

| Consignee: | Shipper:<br><br>Site: |
|---|---|
| Route: | Vehicle Initial and Number: |

| No. Pkgs. | HM | Description of Material | Weight (tons) | Class | Charges |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Subject to section 7 of conditions of applicable Bill of Lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement:
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.
N/A
Signature of the Consignor

If freight charges are to be pre-paid, write or stamp here "TO BE PREPAID".
N/A

NOTE: Where the rate is dependent on value, shippers are required to state specifically in writing the agreed on value of the property:
The agreed on or declared value of the property is hereby specifically stated by the shipper to be not exceeding:
N/A
$ _____ per _____ (unit)

SS741 Reference
N/A

Label(s) applied:

Placard(s) required:

For additional information contact:

Transportation hereunder is for the U.S. Department of Energy and the actual total transportation charges paid to the carrier(s) by the consignor or consignee are to be reimbursed by the U.S. Government, pursuant to cost reimbursable contract number _____ This may be confirmed by contacting _____ at _____.

**IF THIS BILL OF LADING LISTS HAZARDOUS MATERIALS - NOTE AS FOLLOWS:**

**Emergency Response #** **Radioactive Shipments U.S. Department of Energy** **If delayed in Transit Notify:**

| | |
|---|---|
| This is to certify that the above named materials are properly described, packaged, marked, and labeled, and are in proper condition for transportation according to the applicable regulations of the U.S. Department of Transportation. | This shipment is for the U.S. Department of Energy and the actual total transportation charges paid to the carrier(s) by the consignor or consignee are assignable to, and shall be reimbursed by the U.S. Government and is subject to the terms and conditions set forth in the standard form of the U.S. Government Bill of Lading and to any available special rates or charges. YES ( ) NO (X) |
| Shipper:<br>Contract:<br>Per: _____<br>for U.S. Department of Energy Date: | The additions on the face hereof and the terms and conditions are hereby noted:<br>Carrier: _____<br>Per: _____ Date: _____<br>For _____ |

## *STRAIGHT BILL OF LADING SHORT FORM NOT NEGOTIABLE*

CARRIER: Shipper No:
Carrier No: SCAC No: Date:
Purchase / Customer Order No:

Received, subject to the classifications and tariffs in effect on the date of the issue of this Bill of Lading, the property described below in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned, and destined as indicated below, which said carrier agrees to carry to its usual place of delivery. If on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed as to each carrier of all or any of said route to destination and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all Bill of Lading terms and conditions in the governing classification on the date of shipment. The shipper hereby certifies that he is familiar with all the Bill of Lading terms and conditions in the governing classification and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

| Consignee: | Shipper:<br><br>Site: |
|---|---|
| Route: | Vehicle Initial and Number: |

| No. Pkgs. | HM | Description of Material | Weight (tons) | Class | Charges |
|---|---|---|---|---|---|
| 1 CASK | X | UN 3328, RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, FISSILE, 7, U ENR <20%, 0.85 GBq, SOLID/OXIDE AS UNIRRADIATED FUEL RADIOACTIVE YELLOW-II, TI = 0.7, CSI =100 USE/9289/B(U)F-85 EXCLUSIVE USE SHIPMENT<br><br>EMERGENCY CONTACT: 888-888-8888 | 9090 LBS | | |
| | | | | | |
| | | | | | |

Subject to section 7 of conditions of applicable Bill of Lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement:

The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

N/A
Signature of the Consignor

For additional information contact:

SS741 Reference

N/A

Label(s) applied:

Placard(s) required:

Transportation hereunder is for the U.S. Department of Energy and the actual total transportation charges paid to the carrier(s) by the consignor or consignee are to be reimbursed by the U.S. Government, pursuant to cost reimbursable contract number _____ This may be confirmed by contacting _____ at _____.

**IF THIS BILL OF LADING LISTS HAZARDOUS MATERIALS - NOTE AS FOLLOWS:**
**Emergency Response # 888-888-8888** **Radioactive Shipments** **If delayed in Transit**
**Notify:**
**U.S. Department of Energy**

| This is to certify that the above named materials are properly described, packaged, marked, and labeled, and are in proper condition for transportation according to the applicable regulations of the U.S. Department of Transportation. | This shipment is for the U.S. Department of Energy and the actual total transportation charges paid to the carrier(s) by the consignor or consignee are assignable to, and shall be reimbursed by the U.S. Government and is subject to the terms and conditions set forth in the standard form of the U.S. Government Bill of Lading and to any available special rates or charges. YES ( ) NO ( ) |
|---|---|
| Shipper:<br>Contract:<br>Per: _____<br>for U.S. Department of Energy Date: | The additions on the face hereof and the terms and conditions are hereby noted:<br>Carrier: _____<br>Per: _____ Date: _____<br>For _____ |

# Shipper's Declaration Completion for a Manual Form

**SHIPPER'S DECLARATION FOR DANGEROUS GOODS**

Shipper

10.8.3.1

Air Waybill No. 10.8.3.3

Page of Pages 10.8.3.4

Shipper's Reference Number
*(optional)*

Consignee

10.8.3.2

*For optional use for Company logo name and address*

*Two completed and signed copies of this Declaration must be handed to the operator.*

**WARNING**

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties.

**TRANSPORT DETAILS** 10.8.3.5

This shipment is within the limitations prescribed for: *(delete non-applicable)*

| PASSENGER AND CARGO AIRCRAFT | CARGO AIRCRAFT ONLY |
|---|---|

Airport of Departure: 10.8.3.6

Airport of Destination: 10.8.3.7

Shipment type: *(delete non-applicable)* NON-RADIOACTIVE | RADIOACTIVE 10.8.3.8

NATURE AND QUANTITY OF DANGEROUS GOODS

| Dangerous Goods Identification | | | | | | |
|---|---|---|---|---|---|---|
| UN or ID No. | Proper Shipping Name | Class or Division (Subsidiary Risk) | Packing Group | Quantity and type of packing | Packing Inst. | Authorization |
| Step 1 | from 10.8.3.9<br>Step 2 | Step 3 | Step 4 | Steps 5,6,7 | Step 8 | Steps 9,10 |

Additional Handling Information

10.8.3.11

**I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations. I declare that all of the applicable air transport requirements have been met.**

Name/Title of Signatory 10.8.3.13

Place and Date 10.8.3.14

Signature *(see warning above)* 10.8.3.15

10.8.3.12

## Shipper's Declaration Completion — Example 2

**SHIPPER'S DECLARATION FOR DANGEROUS GOODS**

Shipper
ADVANCED CHEMICAL CO.
345 MAIN STREET
REIGATE, SURREY, ENGLAND

Air Waybill No. 800 1234 5686

Page 1 of 1 Pages

Shipper's Reference Number (optional) 1213 / A12

Consignee
ABC Co.Ltd.
1000 HIGH STREET
ATHENS, GREECE

*For optional use for Company logo name and address*

*Two completed and signed copies of this Declaration must be handed to the operator.*

**WARNING**

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties.

**TRANSPORT DETAILS**

This shipment is within the limitations prescribed for: *(delete non-applicable)*

PASSENGER AND CARGO AIRCRAFT ~~CARGO AIRCRAFT ONLY~~

Airport of Departure: LONDON

Airport of Destination: ATHENS

Shipment type: *(delete non-applicable)* ~~NON-RADIOACTIVE~~ RADIOACTIVE

NATURE AND QUANTITY OF DANGEROUS GOODS

| Dangerous Goods Identification | | | | | | |
|---|---|---|---|---|---|---|
| UN or ID No. | Proper Shipping Name | Class or Division (Subsidiary Risk) | Packing Group | Quantity and type of packing | Packing Inst. | Authorization |
| UN2916 | RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE | 7 | | IRIDIUM - 192 SPECIAL FORM 1 TYPE B(U) PACKAGE X 1.925 TBq | II-YELLOW 113.0 DIM 30x30 x40CM | SPECIAL FORM CERTIFICATE Nº 9999 TYPE B(U) PACKAGE CERTIFICATE UK1735/ B(U)S ATTACHED |

Additional Handling Information

**I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations. I declare that all of the applicable air transport requirements have been met.**

Name/Title of Signatory
A. BROWN, SHIPPING MANAGER

Place and Date
REIGATE, 1 JAN 2006

Signature *(see warning above)* A. Brown

## MULTIMODAL DANGEROUS GOODS FORM

This form may be used as a dangerous goods declaration as it meets the requirements of SOLAS 74, chapter VII, regulation 4; MARPOL 73/78, Annex III, regulation 4.

| | | | |
|---|---|---|---|
| 1 Shipper/Consignor/Sender | 2 Transport document number | | |
| | 3 Page 1 of pages | 4 Shipper's reference | |
| | | 5 Freight forwarder's reference | |
| 6 Consignee | 7 Carrier (to be completed by the carrier) | | |
| | **SHIPPER'S DECLARATION**<br>I hereby declare that the contents of this consignment are fully and accurately described below by the Proper Shipping Name, and are classified, packaged, marked and labelled/placarded and are in all respects in proper condition for transport according to the applicable international and national governmental regulations. | | |
| 8 This shipment is within the limitations prescribed for: (Delete non-applicable)<br>PASSENGER AND CARGO AIRCRAFT / CARGO AIRCRAFT ONLY | 9 Additional handling information | | |
| 10 Vessel/flight No. and date | 11 Port/place of loading | | |
| 12 Port/place of discharge | 13 Destination | | |

| 14 Shipping marks | * Number and kind of packages; description of goods | Gross mass (kg) | Net mass (kg) | Cube ($m^3$) |
|---|---|---|---|---|
| | | | | |

| 15 Container identification No./ vehicle registration No. | 16 Seal number(s) | 17 Container/vehicle size & type | 18 Tare mass (kg) | 19 Total gross mass (including tare) (kg) |
|---|---|---|---|---|
| | | | | |

| | | |
|---|---|---|
| **CONTAINER/VEHICLE PACKING CERTIFICATE**<br>I hereby declare that the goods described above have been packed/loaded into the container/vehicle identified above in accordance with the applicable provisions.†<br>**MUST BE COMPLETED AND SIGNED FOR ALL CONTAINER/ VEHICLE LOADS BY PERSON RESPONSIBLE FOR PACKING/ LOADING** | 21 RECEIVING ORGANIZATION RECEIPT<br>Received the above number of packages/containers/trailers in apparent good order and condition, unless stated hereon: RECEIVING ORGANIZATION REMARKS: | |
| 20 Name of company | Haulier's name<br>Vehicle reg. no. | 22 Name of company (OF SHIPPER PREPARING THIS NOTE) |
| Name/status of declarant | Signature and date | Name/status of declarant |
| Place and date | | Place and date |
| Signature of declarant | DRIVER'S SIGNATURE | Signature of declarant |

* **DANGEROUS GOODS:**
You must specify: Proper Shipping Name, hazard class, UN No., packing group, (where assigned) marine pollutant and observe the mandatory requirements under applicable national and international governmental regulations. For the purposes of the IMDG Code see 5.4.1.4.

† For the purposes of the IMDG Code, see 5.4.2.

## Documentary Aspects of the International Transport of Dangerous Goods

### Container/Vehicle Packing Certificate

The signature given overleaf in Box 20 must be that of the person controlling the container/vehicle operation.

It is certified that:

The container/vehicle was clean, dry and apparently fit to receive the goods.

If the consignments include goods of class 1, other than division 1.4, the container is structurally serviceable.

No incompatible goods have been packed into the container/vehicle unless specially authorized by the competent authority.

All packages have been externally inspected for damage and only sound packages packed.

Drums have been stowed in an upright position unless otherwise authorized by the competent authority.

All packages have been properly packed and secured in the container/vehicle.

When materials are transported in bulk packagings the cargo has been evenly distributed in the container/vehicle.

The packages and the container/vehicle have been properly marked, labelled and placarded. Any irrelevant mark, labels and placards have been removed.

When solid carbon dioxide ($CO_2$ – dry ice) is used for cooling purposes, the vehicle or freight container is externally marked or labelled in a conspicuous place, e.g. at the door end, with the words: DANGEROUS $CO_2$ GAS (DRY ICE) INSIDE – VENTILATE THOROUGHLY BEFORE ENTERING.

When this Dangerous Goods Form is used as a container/vehicle packing certificate only, not a combined document, a dangerous goods declaration signed by the shipper or supplier must have been issued/received to cover each dangerous goods consignment packed in the container.

**Note:** The container packing certificate is not required for tanks

**MULTIMODAL DANGEROUS GOODS FORM**

This form maybe used as a dangerous good declaration as it meets the requirements of SOLAS 74, Chapter Regulation 4; MAROL 73/78, Annex III, Regulation 4.

| | | |
|---|---|---|
| 1. Shipper/ Consignor/ Sender | 2. Transport document number: TLIH13 | |
| USDOE<br>OAK RIDGE, TN<br>USA | 3. Page 1 of __1__ pages | Shipper's Reference no.: 5865 |
| | | 5. Freight Forwarder's Reference: |
| 6. Consignee | 7. Carrier (to be completed by carrier): | |
| COMMISSARIAT A 1 ENERGIA ATOMIQUE<br>ATALANTE LABORATORY<br>FRANCE | **SHIPPERS DECLARATION**<br>I hereby declare that the contents of this consignment are fully and accurately described below by the Proper Shipping Name, and are classified, packaged, marked and labeled/ placarded and are in all respects in proper condition for transport according to the applicable international and national governments | |
| 8. This shipment is within limitations prescribed for (Delete non-applicable) | 9. Additional Handling Information | |
| ~~PASSGENGER & CARGO AIRCRAFT~~ | ~~CARGO AIRCRAFT ONLY~~ | EMERGENCY CONTACT: 1-865-888-8888 |
| 10. Vessel/flight no and date<br>TLI AQUILA 013 | 11. Port/ Place of Loading<br>CAMDEN NJ | |
| 11. Port/ Place of discharge<br>LEHARVE | 12. Destination<br>FRANCE | |

| 14. Shipping marks | *Number and kind of packages, description of goods | Gross mass (kg) | Net mass (kg) | Cube (m²) |
|---|---|---|---|---|
| 1 Freight Container | RQ UN2916, RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, CLASS 7<br>Pu-241, Am-243, Pu-240, as solid oxide, 1.29 TBq<br>Category I-White, Fissile Excepted<br>Packaged in (1) Croft 2799E Type B(U) container<br>Cert. No. USA/6788/B()U)-85<br>GB/2799E/B(U)-85<br>Transport Schedule 10<br>EMS No F-1, S-S | 57 kg | | |

| Container identification No. / Vehicle registration No. | 16. Seal Number (s) | 17. Container vehicle size and type | 18. Tare mass (kg) | 19. Total gross including tare (kg) |
|---|---|---|---|---|
| TLIC 2011003 | BIOO79 | 20' STANDARD | | 2367 KG |

| | | |
|---|---|---|
| **CONTAINER VEHICLE PACKING CERTIFICATE**<br>I hereby declare that the goods described above have been packaged/ loaded into the container/ vehicle identified above in accordance with the applicable provisions<br><br>**MUST BE COMPLETED AND SIGNED FOR ALL CONTAINER/VEHICLE LOADS BY PERSON RESPONSIBLE FOR PACKING/ LOADING** | 21. RECEIIVING ORGANIZATION RECEIPT<br><br>Received the above number of packages/ container/ trailers in apparent good order and Condition, unless state hereon: RECEIVING ORGANIZATION REMARKS | |
| 20. Name of company<br>USDOE | Hauler's Name: CHUCK'S TRUCKING | 22. Name of company (shipper preparing this note)<br>USDOE CONTRACTOR |
| Name/Status of Delclarant: | Vehicle registration No.: 12689<br><br>Signature and date | Name/Status of Delcarant: |
| Place and date: OAK RIDGE, TN USA 02/17/08 | | Place and date: OAK RIDGE, TN USA 02/17/08 |
| Signature of Declarant | Signature of Driver | Signature of Declarant |

**DANGEROUS GOODS**

- You must specify: Proper Shipping Name, hazard class, UN No. packing group, (where assigned) marine pollutant and observe the mandatory requirements under applicable national and international governmental regulations. For the purpose of the IMDG Code, see 5.4.1.4.
- For the purpose of the IMDG see 5.4.2.

# UNIFORM HAZARDOUS WASTE MANIFEST

Please print or type. (Form designed for use on elite (12-pitch) typewriter.)

Form Approved. OMB No. 2050-0039

GENERATOR

| UNIFORM HAZARDOUS WASTE MANIFEST | 1. Generator ID Number | 2. Page 1 of | 3. Emergency Response Phone | 4. Manifest Tracking Number |
|---|---|---|---|---|

5. Generator's Name and Mailing Address — Generator's Site Address (if different than mailing address)

Generator's Phone:

6. Transporter 1 Company Name — U.S. EPA ID Number

7. Transporter 2 Company Name — U.S. EPA ID Number

8. Designated Facility Name and Site Address — U.S. EPA ID Number

Facility's Phone:

| 9a. HM | 9b. U.S. DOT Description (including Proper Shipping Name, Hazard Class, ID Number, and Packing Group (if any)) | 10. Containers No. | 10. Containers Type | 11. Total Quantity | 12. Unit Wt./Vol. | 13. Waste Codes |
|---|---|---|---|---|---|---|
| | 1. | | | | | |
| | 2. | | | | | |
| | 3. | | | | | |
| | 4. | | | | | |

14. Special Handling Instructions and Additional Information

15. GENERATOR'S/OFFEROR'S CERTIFICATION: I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labeled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations. If export shipment and I am the Primary Exporter, I certify that the contents of this consignment conform to the terms of the attached EPA Acknowledgment of Consent.
I certify that the waste minimization statement identified in 40 CFR 262.27(a) (if I am a large quantity generator) or (b) (if I am a small quantity generator) is true.

Generator's/Offeror's Printed/Typed Name — Signature — Month Day Year

INT'L

16. International Shipments ☐ Import to U.S. ☐ Export from U.S. Port of entry/exit:

Transporter signature (for exports only): Date leaving U.S.:

TRANSPORTER

17. Transporter Acknowledgment of Receipt of Materials

Transporter 1 Printed/Typed Name — Signature — Month Day Year

Transporter 2 Printed/Typed Name — Signature — Month Day Year

DESIGNATED FACILITY

18. Discrepancy

18a. Discrepancy Indication Space ☐ Quantity ☐ Type ☐ Residue ☐ Partial Rejection ☐ Full Rejection

Manifest Reference Number:

18b. Alternate Facility (or Generator) — U.S. EPA ID Number

Facility's Phone:

18c. Signature of Alternate Facility (or Generator) — Month Day Year

19. Hazardous Waste Report Management Method Codes (i.e., codes for hazardous waste treatment, disposal, and recycling systems)

| 1. | 2. | 3. | 4. |
|---|---|---|---|

20. Designated Facility Owner or Operator: Certification of receipt of hazardous materials covered by the manifest except as noted in Item 18a

Printed/Typed Name — Signature — Month Day Year

EPA Form 8700-22 (Rev. 1-04) Previous editions are obsolete.

DESIGNATED FACILITY TO DESTINATION STATE (IF REQUIRED)

Please print or type. (Form designed for use on elite (12-pitch) typewriter.) Form Approved. OMB No. 2050-00

| UNIFORM HAZARDOUS WASTE MANIFEST | 1. Generator ID Number | 2. Page 1 of | 3. Emergency Response Phone | 4. Manifest Tracking Number |
|---|---|---|---|---|
| | TN12345678910 | 1 | 865 481 4808 | XY46 |

5. Generator's Name and Mailing Address
DOE CONTRACTOR
OAK RIDGE, TN 37831
Generator's Phone: 865 481 4808

Generator's Site Address (if different than mailing address)

6. Transporter 1 Company Name: DOE TRANSPORTER — U.S. EPA ID Number: TN1012345678

7. Transporter 2 Company Name — U.S. EPA ID Number:

8. Designated Facility Name and Site Address
OUT WEST DISPOSAL
PLOWED EARTH, UT 84101
Facility's Phone: — U.S. EPA ID Number: UT9876542310

| 9a. HM | 9b. U.S. DOT Description (including Proper Shipping Name, Hazard Class, ID Number, and Packing Group (if any)) | 10. Containers No. | 10. Containers Type | 11. Total Quantity | 12. Unit Wt/Vol. | 13. Waste Codes | | |
|---|---|---|---|---|---|---|---|---|
| RQ | 1. UN 2913 WASTE RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-II), 7 (D008), solid/oxide 60Co, 152Eu, 154Eu, 151MBq | 1 | CM | 1015 | K | D006 | D008 | |
| RQ | 2. NA3077 HAZARDOUS WASTE, SOLID, N.O.S, 9, III (D006, D008) | 2 | CM | 3789 | K | D006 | D008 | |
| | 3. | | | | | | | |
| | 4. | | | | | | | |

14. Special Handling Instructions and Additional Information
EXCLUSIVE USE SHIPMENT

15. GENERATOR'S/OFFEROR'S CERTIFICATION: I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labeled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations. If export shipment and I am the Primary Exporter, I certify that the contents of this consignment conform to the terms of the attached EPA Acknowledgment of Consent.
I certify that the waste minimization statement identified in 40 CFR 262.27(a) (if I am a large quantity generator) or (b) (if I am a small quantity generator) is true.

Generator's/Offeror's Printed/Typed Name: DOE SHIPPER / ON BEHALF OF THE US DOE — Signature: Joe Shipper — Month 4 Day 1 Year 08

INT'L
16. International Shipments ☐ Import to U.S. ☐ Export from U.S. Port of entry/exit:
Transporter signature (for exports only): Date leaving U.S.:

TRANSPORTER
17. Transporter Acknowledgment of Receipt of Materials
Transporter 1 Printed/Typed Name: TOM DRIVER — Signature: T. Driver — Month 4 Day 1 Year 08
Transporter 2 Printed/Typed Name — Signature — Month Day Year

DESIGNATED FACILITY
18. Discrepancy
18a. Discrepancy Indication Space ☐ Quantity ☐ Type ☐ Residue ☐ Partial Rejection ☐ Full Rejection
Manifest Reference Number:
18b. Alternate Facility (or Generator) — U.S. EPA ID Number
Facility's Phone:
18c. Signature of Alternate Facility (or Generator) — Month Day Year
19. Hazardous Waste Report Management Method Codes (i.e., codes for hazardous waste treatment, disposal, and recycling systems)
1. 2. 3. 4.
20. Designated Facility Owner or Operator: Certification of receipt of hazardous materials covered by the manifest except as noted in Item 18a
Printed/Typed Name — Signature — Month Day Year

EPA Form 8700-22 (Rev. 3-05) Previous editions are obsolete. DESIGNATED FACILITY TO DESTINATION STATE (IF REQUIRED)

EXPIRES: 05/31/2001

Forward comments regarding burden estimate to the Records Management Branch (T-6 F33), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, and to the Paperwork Reduction Project (3150-0164), Office of Management and Budget Washington, DC 20503. If an information collection does not display a currently valid OMB control number, the NRC may not conduct or sponsor, and a person is not required to respond to, the information collection.

**NRC FORM 540** (5-1998) **U. S. NUCLEAR REGULATORY COMMISSION**

# UNIFORM LOW-LEVEL RADIOACTIVE WASTE MANIFEST

## SHIPPING PAPER

1. EMERGENCY TELEPHONE NUMBER *(Include Area Code)*

ORGANIZATION

2. IS THIS AN "EXCLUSIVE USE" SHIPMENT? ☐ YES ☐ NO

3. TOTAL NUMBER OF PACKAGES IDENTIFIED ON THIS MANIFEST =====>

4. DOES EPA REGULATED WASTE REQUIRING A MANIFEST ACCOMPANY THIS SHIPMENT? ☐ YES ☐ NO
If "Yes," provide Manifest Number =====>

EPA MANIFEST NUMBER

5. SHIPPER -- NAME AND FACILITY

SHIPPER I.D. NUMBER

☐ COLLECTOR
☐ PROCESSOR

USER PERMIT NUMBER | SHIPMENT NUMBER | GENERATOR TYPE *(Specify)*

CONTACT | TELEPHONE NUMBER (Include Area Code)

6. CARRIER -- Name and Address | EPA I.D. NUMBER

SHIPPING DATE

CONTACT | TELEPHONE NUMBER (Include Area Code)

SIGNATURE -- *Authorized carrier acknowledging waste receipt* | DATE

7. NRC FORM 540 AND 504A PAGE 1 OF _____ PAGE(S)
NRC FORM 541 AND 541A _____ PAGE(S)
NRC FORM 542 AND 542A _____ PAGE(S)
ADDITIONAL INFORMATION _____ PAGE(S)

8. MANIFEST NUMBER (Use this number on all continuation pages)

9. CONSIGNEE -- Name and Facility Address | CONTACT

TELEPHONE NUMBER *(Include Area Code)*

SIGNATURE -- *Authorized consignee acknowledging waste receipt* | DATE

10. CERTIFICATION

This is to certify that the 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. This also certifies that the materials are classified, packaged, marked, and labeled and are in proper condition for transportation and disposal as described in accordance with the applicable requirements of 10 CFR Parts 20 and 61, or equivalent state regulations.

AUTHORIZED SIGNATURE | TITLE | DATE

| 11. U.S. DEPARTMENT OF TRANSPORTATION DESCRIPTION (Including proper shipping name, hazard class, UN ID number, and any additional information) | 12. DOT LABEL "RADIOACTIVE" | 13. TRANSPORT INDEX | 14. PHYSICAL AND CHEMICAL FORM | 15. INDIVIDUAL RADIONUCLIDES | 16. TOTAL PACKAGE ACTIVITY IN SI UNITS | 17. LSA/SCO CLASS | 18. TOTAL WEIGHT OR VOLUME *(Use appropriate units)* | 19. IDENTIFICATION NUMBER OF PACKAGE |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
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FOR CONSIGNEE USE ONLY

NRC FORM 540 (5-1998)

APPROVED BY OMB: NO. 3150-0166
EXPIRES: 05/31/2001

Estimated burden per response to comply with this information collection request: 5.43 hours. The uniform manifest is required by NRC to meet reporting requirements of 10 CFR and State [illegible] waste. Forward comments regarding burden estimate to the Records Management Branch (T-6 F33), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, and to the Paperwork Reduction Project (3150-0166), Office of Management and Budget, Washington, DC 20503. If an information collection does not display a currently valid OMB control number, the NRC may not conduct or sponsor, and a person is not required to respond to, the information collection.

NRC FORM 541
(5-1998)

U.S. NUCLEAR REGULATORY COMMISSION

# UNIFORM LOW-LEVEL RADIOACTIVE WASTE MANIFEST

## CONTAINER AND WASTE DESCRIPTION

Additional Nuclear Regulatory Commission (NRC) Requirements for Control, Transfer and Disposal of Radioactive Waste

**1. MANIFEST TOTALS**

| NUMBER OF PACKAGES/ DISPOSAL CONTAINERS | NET WASTE VOLUME ($m^3$) | NET WASTE WEIGHT (kg) | SPECIAL NUCLEAR MATERIAL (grams) U-233 | U-235 | Pu | TOTAL |
|---|---|---|---|---|---|---|
| | | | | | | |

| ACTIVITY (MBq) ALL NUCLIDES | TRITIUM | C-14 | Tc-99 | I-129 | SOURCE (kg) |
|---|---|---|---|---|---|
| | | | | | |

2. MANIFEST NUMBER

3. PAGE 1 OF _____ PAGE(S)

4. SHIPPER NAME

SHIPPER ID NUMBER

**DISPOSAL CONTAINER DESCRIPTION / WASTE DESCRIPTION FOR EACH WASTE TYPE IN CONTAINER**

| 5. CONTAINER IDENTIFICATION NUMBER/ GENERATOR ID NUMBER(S) | 6. CONTAINER DESCRIP-TION (See Note 1) | 7. VOLUME ($m^3$) | 8. WASTE AND CONTAINER WEIGHT (kg) | 9. SURFACE RADIATION LEVEL (µSv/hr) (mSv/hr) | 10. SURFACE CONTAMINATION MBq/100 $cm^2$ ALPHA | BETA-GAMMA | PHYSICAL DESCRIPTION 11. WASTE DESCRIP-TOR (See Note 2) | 12. APPROXIMATE WASTE VOLUME(S) IN CONTAINER | 13. SORBENT SOLIDIFICATION, STABILIZATION, MEDIA (See Note 3) | 14. CHEMICAL DESCRIPTION CHEMICAL FORM/ CHELATING AGENT | WEIGHT % CHELATING AGENT IF > 0.1% | 15. RADIOLOGICAL DESCRIPTION INDIVIDUAL RADIONUCLIDES AND ACTIVITY (MBq) AND CONTAINER TOTAL; OR CONTAINER TOTAL ACTIVITY AND RADIONUCLIDE PERCENT | 16. WASTE CLASSIFI-CATION AS-Class A Stable AU-Class A Unstable B-Class B C-Class C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

**NOTE 1: Container Description Codes. For containers/ waste requiring disposal in approved structural overpacks, the numerical code must be followed by "-OP."**

1. Wooden Box or Crate
2. Metal Box
3. Plastic Drum or Pail
4. Metal Drum or Pail
5. Metal Tank or Liner
6. Concrete Tank or Liner
7. Polyethylene Tank or Liner
8. Fiberglass Tank or Liner
9. Demineralizer
10. Gas Cylinder
11. Bulk, Unpackaged Waste
12. Unpackaged Components
13. High Integrity Container
19. Other. Describe in item 6, or additional page

**Note 2: Waste Descriptor Codes. (Choose up to three which predominate by volume.)**

20. Charcoal
21. Incinerator Ash
22. Soil
23. Gas
24. Oil
25. Aqueous Liquid
26. Filter Media
27. Mechanical Filter
28. EPA or State Hazardous
29. Demolition Rubble
30. Cation Ion-exchange Media
31. Anion Ion-exchange Media
32. Mixed Bed Ion-exchange Media
33. Contaminated Equipment
34. Organic Liquid (except oil)
35. Glassware or Labware
36. Sealed Source/Device
37. Paint or Plating
38. Evaporator Bottoms/Sludges/Concentrates
39. CompactibleTrash
40. Noncompactible Trash
41. Animal Carcass
42. Biological Material (except animal carcass)
43. Activated Material
59. Other. Describe in item 11, or additional page

**Note 3: For solidification media that meet disposal site structural stability requirements, the numerical code must be followed by "-S." For all solidification media, the vendor (manufacturer) and brand name must also be identified in Item 13. Code 100=NONE REQUIRED.**

Sorption

60. Speedi Dri
61. Celetom
62. Floor Dry/ Superfine
63. Hi Dri
64. Safe T Sorb
65. Safe N Dri
66. Florco
67. Florco X
68. Solid A Sorb
69. Chemsil 30
70. Chemsil 50
71. Chemsil 3030
72. Dicaperl HP200
73. Dicaperl HP500
74. Petroset
75. Petroset II
76. Aquaset
77. Aquaset II
89. Other. Describe in item 13, or additional page

Solidification

90. Cement (encapsulation)
91. Concrete
92. Bitumen
93. Vinyl Chloride
94. Vinyl Ester Styrene
99. Other. Describe in item 13, or additional page
100. None Required

## 9.19 REVIEW QUESTION SET 16

1. By highway, one 5-gallon DOT 7A Type A package containing radiation standards in four inner poly bottles. Two of the bottles each contain 1.5 E-1 MBq of $^{230}$Th in a nitric acid solution. One bottle contains 1.92 E-1 MBq of $^{237}$Np in hydrochloric acid, and the other contains 0.22 MBq of $^{90}$Sr in hydrochloric acid. All of the solutions meet Class 8, Packing Group II, criteria. The maximum surface dose rate on the package is 0.42 mrem/hr, and the 1-meter reading is 0.1 mrem/hr. The gross weight of the package is 30 lb. The emergency response number is 865-481-4808.

| NO. PKGS. | HM | DESCRIPTION OF MATERIAL | WEIGHT |
|---|---|---|---|
| 1 DRUM | | UN 2915, RADIOACTIVE MATERIAL, TYPE A PACKAGE, 7 (8) $^{230}$Th, $^{237}$Np, $^{90}$Sr, 0.712 MBq, LIQUID/NITRIC AND HYDROCHLORIC ACID SOLUTIONS, TI = 0.1 RADIOACTIVE YELLOW-II AND CORROSIVE LABELS<br><br>Emergency Contact: 865-481-4808 | 30 LB |

- What markings are required? Radioactive Material, Type A Package, UN 2915 USA DOT 7A, Names/Addresses, Orientation Arrows
- What labels are required? RADIOACTIVE YELLOW-II and CORROSIVE
- What placards are required? None

| | | | |
|---|---|---|---|
| $^{237}$Np | 0.19 E-6 TBq | RQ = 370 MBq | $A_2$ = 0.002 TBq |
| $^{230}$Th | (2) 0.15 E-6 TBq = 0.30 | RQ = 370 MBq | $A_2$ = 0.001 TBq |
| $^{90}$Sr | 0.22 E-6 TBq | RQ = 3700 MBq | $A_2$ = 0.002 TBq |

2. To be transported by rail, 5 Type A, USA/6553/AF packages (overpack with inner 10-ton cylinder), each containing 9800 kg (18.61 GBq U enriched <20%) of solid $UF_6$ at 2.0% enrichment. Each package weighs 37,500 lb. The radiation level at the surface of each cylinder is 40 mrem/hr, and the TI is 0.7. The U daughters are not in secular equilibrium. The package is a bulk packaging, and the Certificate of Compliance states that the CSI is 0.4. The emergency response number is 865-481-4808.

| NO. PKGS. | HM | DESCRIPTION OF MATERIAL | WEIGHT |
|---|---|---|---|
| 5 CYLS | RQ | UN 2977, RADIOACTIVE MATERIAL, URANIUM HEXAFLUORIDE, FISSILE, 7(8)<br>TOTAL ACTIVITY: 93 GBq<br><br>EACH CYLINDER CONTAINS: 18.61 GBq,<br>U (ENR 20% OR LESS), SOLID/URANIUM HEXAFLUORIDE,<br>RADIOACTIVE YELLOW-II AND CORROSIVE LABELS<br>TI = 0.7<br>CSI = 0.4<br><br>USA/6553/AF<br>Emergency Contact: 865-481-4808 | 37,000 LB EA. |

- What markings are required? UN 2977, Type A, Gross Weight, USA/6553/AF, Names/Addresses
- What labels are required? RADIOACTIVE YELLOW-II, CORROSIVE, FISSILE
- What placards are required? CORROSIVE (RADIOACTIVE optional)

RQ = 0.0037 TBq = 3.7 GBq

3. By highway, a shipment of externally-contaminated equipment. There is a total activity of 32.2 MBq of U enriched <5%, $^{230}$Th, and $^{237}$Np. The material meets the SCO-II criteria, and it will be shipped in an intermodal bulk container. The gross weight is 39,000 lb. There are 14.35 g of $^{235}$U. The maximum radiation level at 3 meters from the unpackaged material is 2 mrem/hr. The surface dose rate at the package surface is 0.01 mrem/hr. The emergency response number is 865-481-4808.

| NO. PKGS. | HM | DESCRIPTION OF MATERIAL | WEIGHT |
|---|---|---|---|
| 1 CONTAINER | | UN 2913, RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-II), 7,<br>$^{230}$Th, $^{237}$Np, U (ENR. 20% OR LESS), 32.2 MBq,<br>SOLID/METAL, SCO-II<br>FISSILE EXCEPTED<br>EXCLUSIVE USE SHIPMENT<br><br>Emergency Contact: 865-481-4808 | 39,000 LB |

- What markings are required? RADIOACTIVE–SCO
- What labels are required? None
- What placards are required? RADIOACTIVE

4. By air, an authorized package weighing 1.8 kg and containing 6 kBq of $^{3}H$ and 3 kBq of $^{14}C$ in 80 mL (112 g) of toluene. The surface dose reading on the package is <0.05 mrem/hr. The toluene meets the Packing Group II criteria. The emergency response number is 865-481-4808.

| | | | | | | |
|---|---|---|---|---|---|---|
| Shipper | | | | Air Waybill No<br>Page of pages<br>Shipper's Reference Number | | |
| Consignee | | | | | | |
| This shipment is within the limitations prescribed for: (delete nonapplicable) | | Airport of Departure | | WARNING<br>Failure to comply in all respects with the applicable *Dangerous Goods Regulations* may be in breach of the applicable law, subject to legal penalties, | | |
| PASSENGER AND CARGO AIRCRAFT | ~~CARGO AIRCRAFT ONLY~~ | | | | | |
| Airport of Destination: | | | Shipment type: (delete nonapplicable)<br>NONRADIOACTIVE / ~~RADIOACTIVE~~ | | | |
| NATURE AND QUANTITY OF DANGEROUS GOODS | | | | | | |
| UN or ID no. | Proper Shipping Name | Class or Division (Subsidiary Risk) | Packing Group | Quantity and type of packing | Packing Inst. | Authorization |
| UN 1294 | TOLUENE SOLUTION | 3 | II | (1) 4G FIBRE-BOARD BOX X 80ml | 305 | |
| Additional Handling Information EMERGENCY CONTACT: 865-481-4808 | | | | | | |

- What markings are required? **Toluene Solution, UN 1993, Orientation Arrows, Names/Addresses**

- What labels are required? **FLAMMABLE**

- What placards are required? **None**

**$^{3}H$ exempt values: 1 E6 Bq/g/1 E7 Bq Have: 9000 Bq**
**$^{14}C$ exempt values: 1 E4 Bq/g/1 E9 Bq Have: 9000 Bq/112 g = 8 Bq/g**
**Not regulated as Class 7**

5. By highway, a DOT Specification 6M drum containing 1.9 MBq (24.04 g) of $^{235}U$ as a solid, nonpyrophoric metal. The maximum surface dose rate is 0.4 mrem/hr, and it is 0.1 mrem/hr at 1 meter. The total packaged weight is 124.5 kg. The emergency response number is 865-481-4808. The H/X ratio is 0.

| NO. PKGS | HM | DESCRIPTION OF MATERIAL | WEIGHT |
|---|---|---|---|
| 1 DRUM | X | UN 2918, RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, FISSILE, 7,<br>SOLID/METAL,<br>$^{235}U$, 1.9 MBq<br>RADIOACTIVE YELLOW-II, TI = 0.1<br>CSI = 0.0<br><br>Emergency Contact: 865-481-4808 | 124.5 KG |

- What markings are required? Radioactive Material, Type B(U), Package, Fissile, UN 2918 , Trefoil Symbol, Names/Addresses, Gross Weight = 124.5 kg

- What labels are required? RADIOACTIVE YELLOW-II, FISSILE

- What placards are required? None

  RQ = 0.0037

6. One shipping container, USA/6642/B(U), weighing 9550 lb, will be shipped by highway. The content is 100.6 GBq of californium (Cf) as a solid oxide encapsulated in special form. The isotopic breakdown is $^{249}$Cf (0.64 GBq), $^{250}$Cf (14.6 GBq), $^{251}$Cf (0.13 GBq), $^{252}$Cf (82.9 GBq), curium (Cm)-245 (0.7MBq), $^{246}$Cm (17.2 MBq), $^{248}$Cm (0.5 MBq), and various mixed fission products (2.6 MBq). The reading on the surface of the cask is 13.0 mrem/hr, and it is 1.4 mrem/hr at 1 meter. The emergency response number is 865-481-4808.

| NO. PKGS. | HM | DESCRIPTION OF MATERIAL | WEIGHT |
|---|---|---|---|
| 1 CASK | RQ | UN 2916, RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, 7<br>$^{252}$Cf, $^{250}$Cf<br>SPECIAL FORM, 98.29 GBq,<br>RADIOACTIVE YELLOW-III, TI = 1.4<br><br>USA/6642/B(U)<br><br>Emergency Contact: 865-481-4808 | 9550 LBS. |

- What markings are required? RQ, PSN, ID Number, Type B, USA/6642/B(U), Gross Weight, Trefoil Symbol, Names/Addresses

- What labels are required? RADIOACTIVE YELLOW-III

- What placards are required? RADIOACTIVE

7. By highway, one inner High Flux Isotope Reactor unirradiated fuel element shipping container, USA/5797/B(U)F. There are 0.22 TBq of U enriched to 93% ($^{235}U$, $^{238}U$, and $^{234}U$) as a solid U/aluminum cermet. The package certificate states that the criticality TI is 0.4. The surface radiation reading is 2 mrem/hr, and the reading at 1 meter is 0.1 mrem/hr. The cask is a nonbulk packaging, and the gross weight is 650 lb. The emergency response number is 865-481-4808.

| NO. PKGS | HM | DESCRIPTION OF MATERIAL | WEIGHT |
|---|---|---|---|
| 1 CASK | RQ | UN 3328, RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, FISSILE, 7<br>$^{235}U$, $^{238}U$, $^{234}U$<br>SOLID/U-AL CERMET, 0.22 TBq<br>RADIOACTIVE YELLOW-II, TI = 0.4<br>CSI = 0.4<br><br>USA/5797/B(U)F<br><br>Emergency Contact: 865-481-4808 | 650 LBS |

- What markings are required? RQ, PSN, ID Number, Type B, Gross Weight, Trefoil Symbol, Names/Addresses

- What labels are required? RADIOACTIVE YELLOW-II, FISSILE

- What placards are required? None

$A_2$ = 0.001 TBq
RQ = 0.0037 TBq

# CHAPTER 10
# URANIUM HEXAFLUORIDE

OBJECTIVES

- UNDERSTAND THE CHARACTERISTICS OF $UF_6$.
- UNDERSTAND THE PACKAGING REQUIREMENTS FOR $UF_6$.
- UNDERSTAND THE TRANSPORT REQUIREMENTS FOR $UF_6$.

## 10.1 $UF_6$ PROPERTIES

Uranium hexafluoride ($UF_6$) is a radioactive material having a significant chemical hazard. It is a compound of hexavalent U and fluorine, which is used as the process gas in gaseous diffusion plants to increase the concentration of the fissile isotope $^{235}U$ in the mixture of U isotopes found in naturally occurring U. Under the DOT regulations, the radioactive nature of the material takes precedence, and the chemical hazard (corrosivity) is treated as a subsidiary risk. Depending on the degree of enrichment and the amount of fissile U present, $UF_6$ may be transported (from a radiological standpoint) in excepted, IP, Type A, or fissile packaging.

The cylinders used to transport $UF_6$ are designed to be pressurized during filling and emptying, and they must comply with the pressure vessel standards, even though the cylinders are not pressurized under normal transport conditions. The $UF_6$ is multiphasic in nature and will pass through liquid and gaseous phases while the cylinder is filled, but the material must be a solid when transported.

With respect to its packaging and transport requirements, $UF_6$ is a unique material. During transport, $UF_6$ exists as a crystalline solid and is shipped in metal cylinders at slightly reduced atmospheric pressure. The material presents hazards due to its radioactivity and corrosivity. Breaching a cylinder of solid $UF_6$ would result in a reaction product of the material with the moisture in the air to produce a highly corrosive but moderately radioactive gaseous cloud of material.

Depending on its enrichment in the $^{235}U$ isotope, $UF_6$ is packaged and shipped essentially as either a nonfissile (LSA) material or as a fissile material. When the material is enriched in the $^{235}U$ isotope beyond 1%, it is shipped as and subject to the additional requirements for a fissile radioactive material.

The packaging standards for $UF_6$, both fissile and LSA material, are located in Section 173.420, which details the physical requirements for the pressure cylinders used to process and package $UF_6$. This section contains references to American National Standards Institute (ANSI) Standard N14.1, *Nuclear Materials - Uranium Hexafluoride - Packaging for Transport*, and the United States Enrichment Corporation (USEC) Report USEC-651, *Good Handling Practices for Uranium Hexafluoride*. These documents are extremely important sources of information relative to processing, packaging, and transporting $UF_6$. Many of the requirements for $UF_6$ are imposed by other standards (ANSI N14.1 and the ASME Pressure Vessel Code) that address the physical properties and chemical toxicity hazard posed by $UF_6$ if it is released to the atmosphere and reacts with water or water vapor.

## 10.2 $UF_6$ CYLINDERS AND SHIPPING REQUIREMENTS

Section 173.420 of 49 CFR details the requirements applicable to both fissile and nonfissile $UF_6$. For modern cylinder designs, this section specifies compliance with the provisions in ANSI N14.1 in effect at the time of cylinder manufacture. Older designs were generally manufactured to the ASME Pressure Vessel Code, which is also referenced in Section 173.420. Most of the cylinder designs are discussed in USEC-651.

All $UF_6$ cylinders with greater than 100 g of $UF_6$ must comply with the provisions in Section 173.420, which require each $UF_6$ package to be designed so that it will:

- Withstand a hydraulic test at an internal pressure of 200 lb per square inch without leaking.
- Withstand the free drop test in Section 173.465(c) without loss or dispersal of the $UF_6$.
- Withstand the thermal test in 10 CFR 71.73(c)(4) without rupture of the containment.

These tests do not have to be conducted sequentially or on the same package.

In addition to the provisions in Section 173.420, $UF_6$ shipments are subject to the provisions in either Section 173.427 or 173.417, as referenced in the HMT.

When it is enriched to not more than 1%, $UF_6$ is considered nonfissile and meets the fissile exemption in Section 173.453(d). As such, it can be shipped using the LSA shipping provisions in Section 173.427. This allows the $UF_6$ cylinders to meet the excepted packaging standard.

When it is enriched to more than 1%, $UF_6$ must be shipped in the authorized Type A or Type B fissile packages referenced in Sections 173.417(a)(2) and (3) and in Section 173.417(b)(3).

The quantity limits for shipping enriched (fissile) $UF_6$ in the form of residual "heels" of material in “empty” cylinders are provided in Section 173.417(a)(7). The quantity limits for fissile $UF_6$ in metal cylinders overpacked in DOT Specification 20PF and 21PF protective overpacks are contained in Section 173.417(b)(5) or in the certificates for NRC-certified $UF_6$ packages. The specifications for DOT overpacks are provided in Sections 178.356 and 178.358.

Several NRC Certificates of Compliance for transport have been issued for packages that are used to ship fissile $UF_6$. These include Certificates USA/4909/AF, USA/9196/AF, USA/9234/AF, and USA/6553/AF.

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