

IS RADIOACTIVE MIXED WASTE PACKAGING AND TRANSPORTATION REALLY A PROBLEM?

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ABSTRACT

Recently, there has been significant concern expressed in the nuclear community over the packaging and transportation of radioactive mixed waste under U.S. Department of Transportation regulations. This concern has grown more intense over the last 5 to 10 years. Generators and regulators have realized that much of the waste shipped as "low-level radioactive waste" was in fact "radioactive mixed waste" and that these wastes pose unique transportation and disposal problems. Radioactive mixed wastes must, therefore, be correctly identified and classed for shipment. It must also be packaged, marked, labeled, and otherwise prepared to ensure safe transportation and meet applicable storage and disposal requirements, when established. This paper discusses regulations applicable to the packaging and transportation of radioactive mixed waste and identifies effective methods that waste shippers can adopt to meet the current transportation requirements. This paper will include a characterization and description of the waste, authorized packaging, and hazard communication requirements during transportation. Case studies will be used to assist generators in understanding mixed waste shipment requirements and clarify the requirements necessary to establish a waste shipment program. Although management and disposal of radioactive mixed waste is clearly a critical issue, packaging and transportation of these waste materials is well defined in existing U.S. Department of Transportation hazardous material regulations.

BACKGROUND

In 1954, the United States established the "Atomic Energy Act of 1954" (AEA)(1). This act covered the generation of nuclear and byproduct materials, their management and use, and disposal of the resulting radioactive wastes. Authority for implementing the act fell to the Atomic Energy Commission. Its functions today rest with the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE).

Under authority of the AEA, radioactive waste was packaged and placed directly into shallow land burial trenches located near the waste generation sites. At some sites, this was not possible, so waste was transported as "low-level radioactive waste" to regional disposal facilities like the Hanford Site and the Nevada Test Site.

The regulations issued under the AEA focused on nuclear material generation and use, site management, and waste storage and disposal requirements. However, transportation and packaging requirements were not addressed but deferred to the authority of other federal agencies which eventually became the U.S. Department of Transportation based on the "Hazardous Materials Transportation Act of 1974" (HMTA)(2). At this time, DOT had federal authority for hazardous material transportation safety via all modes of transportation. For certain radioactive materials and wastes, the national security exemption provided limited exceptions [see 49 CFR 173.7(b)](3).

In 1976, the "Resource Conservation and Recovery Act" (RCRA)(4) gave the U.S. Environmental Protection Agency (EPA) the authority to regulate the management and disposal of hazardous wastes. This act specifically exempted radioactive wastes generated at facilities regulated under the AEA but raised many questions. Controversy ensued over application of the RCRA to nonradioactive hazardous wastes and radioactive mixed wastes generated at AEA facilities. For the next 10 years, the debate continued.

In 1986, Federal agency agreements finally gave the EPA and the states regulatory authority for these waste classes.

Although authority was clearly established, discussion continues today over long-term management and disposal issues.

For example, in 1987, the State of Washington accepted authority for establishing radioactive mixed waste management and disposal regulations. By 1988, no written regulations had been issued; yet, the DOE facility at the Hanford Site was influenced to stop burying radioactive mixed wastes and use monitored aboveground storage. In 1992, radioactive mixed waste continues to be stored awaiting issuance of state regulations.

In many other states, no action has been taken to issue regulations covering radioactive mixed waste; therefore, the management and disposal controversy continues.

Although the disposal issue remains unsettled, the packaging and transportation of these wastes should be considered noncontroversial to those familiar with existing DOT hazardous material regulations, that is Title 49, "Code of Federal Regulations" (CFR), 49 CFR 171-179(5, 6, 7, 8, 9, 10, 11, 12, 13). These regulations have remained essentially unchanged since the early 1980's in regard to transportation of multiple hazard materials, including radioactive mixed wastes.

APPLICABLE REGULATIONS

The DOT hazardous material regulations address the packaging and transportation requirements for hazardous materials and hazardous wastes as identified by the DOT and the EPA. These regulations cover hazard classification and description, identify authorized packaging, establish communication standards (e.g., markings, labels, placards, documentation), and specify modal requirements. These regulations specifically identify procedures for classifying and shipping materials that have multiple hazards, like radioactive mixed waste. The classification is based on a hazard class ranking system that is described in 49 CFR 173.2. In most cases, the radioactive hazard takes precedence and determines the resulting packaging and transportation requirements. Compatibility requirements in 49 CFR 173.24 and communication requirements in 49 CFR 172, Subparts C, D, E, F, and G

address the secondary hazard that may be contained in the package.

For cases where the radioactive content qualifies as "limited quantity," specific exceptions apply. These exceptions are identified in 49 CFR 173.421, 173.421-1, and 173.421-2. In general, when a limited quantity of radioactive material also meets the definition of another DOT hazard class, the other hazard class takes precedence. For example, a waste solution meeting the corrosive material hazard class and limited quantity of radioactive material would be classed, packaged, and shipped as a DOT corrosive material. Certain package markings and shipping paper entries are required to address the limited radioactive hazard as found in 49 CFR 173.421-2.

The following sections will define the key elements of a radioactive mixed waste shipment program; case studies provide examples to demonstrate the use of the applicable regulations.

KEY ELEMENTS OF AN EFFECTIVE RADIOACTIVE MIXED WASTE SHIPMENT PROGRAM

Waste Accumulation and Storage

Before radioactive mixed waste can be shipped, it must be fully characterized and prepared for shipment to meet DOT, EPA, and applicable state regulations. This characterization process is often time consuming; therefore, it is necessary to collect and store the waste properly until test results and analyses can be completed. Generator waste storage requirements, if assumed to be equivalent to those for RCRA hazardous wastes, include "satellite accumulation area" and "permitted by rule/90-day" storage. Both storage methods can be used, provided EPA and state requirements and standards are met. Some exceptions do exist for wastes that have been sampled for analysis under 40 CFR 261.4(d)(14).

Satellite accumulation area storage for most RCRA hazardous wastes usually limits the stored quantity of waste to 208 L. There is a 1-L limit for acutely hazardous wastes. When either of these quantity limits are reached the respective waste container must be closed, the accumulation date marked, and moved to a permitted by rule/90-day storage area.

The EPA regulations for satellite accumulation storage areas require placing generated waste in adequate containers. Although not required, it is good management to make the containers DOT approved for the suspected hazard class of the material. The generator must maintain control of all waste accumulations at or near the point of generation, segregate waste types by class and compatibility, and mark each container with the words "Hazardous Waste" or words that identify the suspected hazards in each container (e.g., corrosive, flammable, radioactive). Each area must be properly posted, have a contingency plan, and have appropriate personnel training.

Waste moved from the satellite accumulation areas must be moved to an EPA permitted Treatment, Storage, and Disposal (TSD) facility or to a permitted by rule/90-day storage area. The 90-day storage area must meet specified standards addressed by the EPA in 40 CFR 265(15), which covers container or tank management, secondary containment structures, personnel training, contingency plans, and emergency preparedness and response. Storage beyond the 90-day limit must be in EPA-permitted TSD facilities meeting standards

specified in 40 CFR 264(16) and 265 unless an extension has been granted.

When a generator accumulates and stores their own hazardous wastes, as summarized previously, they must keep detailed records of all tests and analyses, waste inventories, facility inspections, documentation on all shipments, and file reports with EPA and with the authorized state on a scheduled basis.

Material and/or Waste Characterization

The most important and sometimes most difficult task in determining correct packaging and transportation requirements is proper characterization and hazard classification. This is especially true for materials that exhibit multiple hazards, like radioactive mixed waste. The generator must know what radionuclides are present, the quantities of each radionuclide, physical and chemical form, and distribution in the waste matrix. In addition, if the waste is a sealed source, the generator must know if it qualifies as "special form" under 49 CFR 173.469. To make these determinations, the generator must have a comprehensive knowledge of the waste source, material and inventory balance, dose rate and source term information, and/or laboratory analysis data.

In many cases, conservative estimates are made from knowledge of the waste source contaminants and dose rate conversions to estimate becquerel (Bq) levels within each waste package.

In addition to determining radiological data, it is necessary to determine if other hazardous characteristics are exhibited by the waste. Also, it is necessary to identify each hazardous constituent as well as its quantity, concentration, and form, and to know the properties the contaminants contribute to the waste matrix. Knowledge of the waste source is vital to minimize the necessity of performing laboratory analysis.

With this data, the waste can be categorized under EPA or applicable state regulations and appropriate waste codes can be assigned. The generator must determine if the waste is an EPA listed waste or if the waste meets specific characteristics (e.g., ignitable, reactive, corrosive, toxic). When using EPA regulations, these lists and defining criteria can be found in 40 CFR 261(17).

For transportation, the generator must identify the DOT hazard class and select a proper shipping name using hazard class criteria found in 49 CFR 173 and the Hazardous Materials Table (HMT) 49 CFR 172.101. When multiple hazards are present, the generator must use 49 CFR 173.2, "Classification of material having more than one hazard..." to determine the correct hazard class for shipment. The proper shipping name selected from the HMT must accurately describe the waste and correspond to the hazard class from the 49 CFR 173.2 precedence list. Any secondary hazards must be considered for compatibility within the transport package and must be addressed through container marking and labeling as well as shipping paper entries.

Packaging

The authorized packaging for the radioactive mixed waste is determined from the HMT (172.101) columns 5(a) and 5(b), based on the hazard class and proper shipping name selected. The DOT regulations list authorized packagings by DOT specification number (e.g., DOT 17C) or by

performance standards [e.g., United Nations (UN) 1A1]. For waste classed other than radioactive [e.g., corrosive material (liquid) with a limited quantity of radioactive material] and classed corrosive material, the packaging reference would likely be 49 CFR 173.245 "Corrosive liquids not specifically provided for."

This packaging reference would authorize DOT specification packages like the DOT 17C closed head drum. If the radioactive content exceeds limited quantity, then the shipper would class the material as radioactive material and select an appropriate proper shipping name based on radioactive content. Most radioactive wastes are described as Radioactive Material, Low Specific Activity N.O.S. or Radioactive Material N.O.S. The packaging references are 49 CFR 173.425, 173.415, and 173.416, respectively. For these materials, the references lead to a small number of DOT specification containers or to performance-based packages authorized by either DOT, DOE, or the NRC (e.g., strong-tight, Type A or Type B packaging). For limited quantity and most low specific activity radioactive wastes, the material can be packaged in strong-tight industrial packages that will retain the material during conditions normally incident to transportation. For Type A radioactive waste, the material must be placed in defined packaging systems, tested, and documented as providing containment during specified test conditions simulating normal conditions of transportation found in 49 CFR 173.465 and 173.466. The package must also be compatible with the payload so that package effectiveness will not be reduced (49 CFR 173.24). For Type B quantities and certain fissile radioactive materials, the packaging system used must demonstrate the ability to withstand hypothetical accident conditions as prescribed in 49 CFR 173.467 and 10 CFR Part 71(18). The testing, evaluation, and analysis of the package and its performance to these standards must consider the potential contribution and impact of the mixed waste constituents identified in the payload.

Transportation Communication Requirements

Container marking and labeling, vehicle placarding, shipping paper, and emergency response information requirements are in 49 CFR 172, Subparts C, D, E, F, and G. These standards communicate potential hazard information for handling and transportation of personnel, the public, and emergency responders. The information provided is necessary for personnel protection, public safety, and protection of the environment during transportation operations. The requirements are driven by the waste type, its DOT hazard class, and any secondary hazards associated with the package content. Handling mixed hazard materials and waste is addressed in each subpart.

Marking requirements are found in 49 CFR 172, Subpart D. Examples of required markings include proper shipping name, identification number [United Nations (UN), North American (NA)], and the name and address of the shipper or receiver. For most mixed hazardous materials, the name of the principle constituents associated with each hazard must be marked on the shipping container associated with the proper shipping name.

Labeling requirements are found in 49 CFR 172, Subpart E. Waste generators are required to label for the DOT hazard class and for any secondary hazards based on listed criteria.

For example, a radioactive material, which is also corrosive, would have both radioactive and corrosive labels applied.

Placarding requirements are found in 49 CFR 172, Subpart F, and are based on DOT hazard class. Secondary hazards normally do not affect the placarding requirements unless the waste also qualifies as a "poison inhalation hazard" per 49 CFR 173.3a. In this situation, multiple placards representing each hazard are required. For example, a flammable liquid also meeting the criteria for a poison inhalation hazard would require flammable and poison placards mounted on the vehicle.

Shipping paper requirements are found in 49 CFR 172, Subpart C. The shipment description must include information such as the number and type of packages, the proper shipping name, hazard class and UN/NA identification number for each package. For packages containing mixed hazards, the secondary hazard class may be entered in parentheses within the basic description. For example, a radioactive material also meeting flammable solid criteria would have a description like "Radioactive Material N.O.S. (Flammable Solid) UN2982."

Emergency Response Information

Emergency response information is located in 49 CFR 172, Subpart G. The requirements include incorporating or attaching the emergency response and accident mitigation information applicable to the material being shipped to the shipping paper. Minimum guidelines for the type of information and how it is to be presented are addressed by the DOT in 49 CFR 172.602. The second part of the emergency response information requirements is the inclusion of an emergency contact telephone number on the shipping paper. Very strict requirements apply as to the location of this telephone number, and especially to the availability of someone answering at any time the shipment is in transport. Also, the individual answering the telephone must be knowledgeable or have direct access to a person who is knowledgeable about the hazards of the materials so as to mitigate an accident situation.

Case Studies

The case studies that follow show how these requirements are applied to radioactive mixed waste shipments. These specific examples are not to be considered all inclusive of the regulations that may apply. Many states apply additional and somewhat different regulations that go beyond what DOT and EPA require for shipment safety. (See Figs. 1-4)

REFERENCES

1. ATOMIC ENERGY ACT OF 1954, 42 USC 2011 et seq.
2. HAZARDOUS MATERIALS TRANSPORTATION ACT OF 1974, 46 USC 170, 49 USC 103 et seq.
3. "U.S. Government Material," 49 CFR 173.7(b), U.S. Department of Transportation.
4. RESOURCE CONSERVATION AND RECOVERY ACT OF 1976, 42 USC 6901, et seq.
5. "General Information, Regulations, and Definitions," 49 CFR 171, U.S. Department of Transportation.
6. "Hazardous Materials Tables, Hazardous Materials Communications Requirements and Emergency Response Information Requirements," 49 CFR 172, U.S. Department of Transportation.

Scenario #1 for Mixed Waste:

Waste material to be prepared for disposal: 409 kg of spent lead acid batteries, with dry residual sulfuric salts, used as power source for emergency backup lights in radioactively contaminated zone.

Dose rate on contact: $<0.5 \mu\text{Sv/h}$
 Isotopes present: traces of ^{137}Cs , ^{137}Ba , ^{90}Sr , and ^{90}Y
 Maximum activity per container: 0.666 MBq

DOT Shipping Paper Basic Description:
 RQ Waste Corrosive Solid, N.O.S. Corrosive Material, UN 1759 (Lead)(contains sulfuric salts) Limited Quantity Radioactive Material

DOT Packagings: DOT 17H painted steel drums with 10-mil polyethylene liner (authorized in 49 CFR 173.245b & 173.421-2)


DOT Label: DOT corrosive label only

DOT Markings: RQ Corrosive Solid, N.O.S. UN 1759 (Lead) (contains sulfuric salts) Radioactive EPA Hazardous Waste Warning Statement and Required Data (see example below).

DOT Placards: None Required.

EPA Hazardous Waste Warning on sticker includes:
 o DOT proper shipping name & identification number (as identified above)
 o Accumulation date
 o Generator information
 o EPA identification number
 o Manifest #, and waste codes
 o Shipper/receiver name & address

DOT Specification Number DOT 17H (on bottom)



DOT Hazard Class Label

DOT and EPA Required Markings and Labels

Fig. 1. Mixed waste scenario #1.

Scenario #2 for Mixed Waste:

Waste material to be prepared for disposal: Liquid mixture of 30 L consisting of ethanol (66%), water (33%), and reacted sodium (1%). Ethanol and water mixture used to decontaminate radioactive sodium from reactor equipment. Two 18-L stainless steel DOT 17C bung drums, each containing 15 L, are packaged into a 208 L DOT 17C open head drum, with a ridged poly liner. Plywood centering supports, absorbent, and lead for shielding were used as part of inner packaging.

Dose rate on contact: $125 \mu\text{Sv/h}$ (inner container), $55 \mu\text{Sv/h}$ at outside
 Isotopes present are: ^{22}Na , ^{45}Sc , ^{51}Cr , ^{54}Mn , ^{50}Co , ^{102}Ta
 Maximum activity per container: 3.7 GBq

DOT Shipping Paper Basic Description:
 Waste Radioactive Material, low specific activity, N.O.S., UN 2912, ^{22}Na , ^{45}Sc , ^{51}Cr , ^{54}Mn , ^{50}Co , ^{102}Ta , liquid, alcohol/water/caustic solution, 3.7 GBq (0.1 curies), Flammable and Corrosive.

DOT Packaging: Packaged low specific activity (LSA) material, consigned as exclusive use, are excepted from specification packaging, marking and labeling. [49 CFR 173.425(b)]

DOT Label: Flammable Liquid & Corrosive Labels (172.402(a))

DOT Markings: Radioactive Material, LSA, N.O.S., UN 2912, Gross weight, "This end up" on top of container, EPA Hazardous Waste Warning Statement, and required data (see example below).

DOT Placards: Radioactive Placards on Vehicle

EPA Hazardous Waste Warning on sticker includes:
 o DOT proper shipping name & identification number (as identified above)
 o Accumulation date
 o Generator information
 o EPA identification number
 o Waste codes
 o Manifest number
 o Shipper/receiver name & address

DOT Specification Number DOT 17C (on bottom)



DOT Hazard Class Labels

DOT and EPA Required Markings and Labels

Fig. 2. Mixed waste scenario #2.

Scenario #3 for Mixed Waste:

Waste material to be prepared for disposal: 38.6 kg of miscellaneous waste consisting of plastic, paper, cloth, absorbent and aluminum parts. Waste is packed in a DOT 17C 208 L steel drum with heavy poly liner. Package authorized as a DOT 7A specification package. Waste generated in maintenance activity includes methyl ethyl ketone and acetone.

Dose rate on contact: $<0.5 \mu\text{Sv/h}$
 Isotopes present are: ^{137}Cs , ^{137}Ba , ^{90}Sr , and ^{90}Y
 Maximum activity per container: 66.6 MBq

DOT Shipping Paper Basic Description:
 Waste Radioactive Material, N.O.S., UN 2982, ^{137}Cs , ^{137}Ba , ^{90}Sr , ^{90}Y , solid, absorbed organics, 66.6 MBq (1.8 mCi), Radioactive White I labels, DOT 7A/Type A container, 38.6 kg

DOT Packaging: DOT Specification 7A Type A shipping container authorized in 49 CFR 173.415.


DOT Label: Radioactive White I labels applied

DOT Markings: Radioactive Material, N.O.S., UN 2982, Gross Weight, Radioactive Materials, DOT 7A Type A, EPA Hazardous Waste Warning Statement, and Required Data (see example below).

DOT Placards: None Required.

EPA Hazardous Waste Warning on sticker also includes:
 o DOT proper shipping name & identification number (as identified above)
 o Accumulation date
 o Generator information
 o EPA identification number
 o Waste codes
 o Manifest number
 o Shipper/receiver name & address

Gross Weight
 DOT Specification Number (178.350)



DOT Hazard Class Label

DOT and EPA Required Markings and Labels

Fig. 3. Mixed waste scenario #3.

Scenario #4 for Mixed Waste:

Waste material prepared for disposal: Methyl isobutyl ketone to be shipped in 18,927-L tank truck. Methyl isobutyl ketone was used in a nuclear process and is contaminated with tritium.

Dose rates: $<0.5 \mu\text{Sv/h}$ at contact. No reading was obtained at 1 M.
 Isotope present is: Tritium
 Activity: 7 GBq

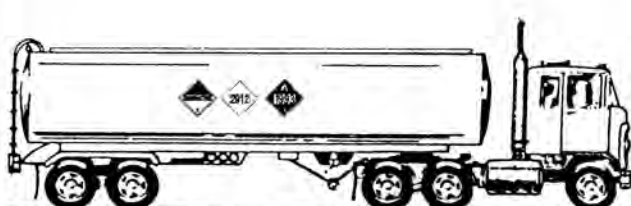
DOT Shipping Paper Basic Description:
 RQ Waste Radioactive Material, Low Specific Activity, N.O.S., UN 2912, T (other forms), Liquid, Organic, 7 GBq (0.19 Ci), (RQ-methyl isobutyl ketone) (Flammable), 18,927 L.

DOT Transport Requirements: Unpackaged (bulk) shipments of LSA material shall be transported only in exclusive use closed transport vehicles with no bottom openings. Specification MC 312 Cargo Tank per 49 CFR 173.425(c)(2)(ii)

DOT Label: None Required.

DOT Markings: As required for specification MC312 Cargo Tank (see example below).

DOT Placards: Radioactive, 2912, Flammable, 1993



DOT and EPA Marking and Placards

Fig. 4. Mixed waste scenario #4.

7. "Shippers--General Requirements for Shipments and Packagings," 49 CFR 173, U.S. Department of Transportation.
8. "Carriage by Rail," 49 CFR 174, U.S. Department of Transportation.
9. "Carriage by Aircraft," 49 CFR 175, U.S. Department of Transportation.
10. "Carriage by Vessel," 49 CFR 176, U.S. Department of Transportation.
11. "Carriage by Public Highway," 49 CFR 177, U.S. Department of Transportation.
12. "Shipping Container Specifications," 49 CFR 178, U.S. Department of Transportation.
13. "Specifications for Tank Cars," 49 CFR 179, U.S. Department of Transportation.
14. "Identification and Listing of Hazardous Waste," 40 CFR 261, U.S. Environmental Protection Agency.
15. "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," 40 CFR 265, U.S. Environmental Protection Agency.
16. "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," 40 CFR 264, U.S. Environmental Protection Agency.
17. "Identification and Listing of Hazardous Waste," 40 CFR 261, U.S. Environmental Protection Agency.
18. "Packaging and Transportation of Radioactive Materials," 10 CFR 71, U.S. Nuclear Regulatory Commission.