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Incoming

Department of Energy
Germantown, MD 20874-1290

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Mr. John Reeves
Manager, Project Engineering
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345 Hills Street
Richland, WA 99352

Dear Mr. Reeves:

The documents entitled "Documentation and Verification Required for Type A Packaging Use" (WMTS-IP/7A-002, Rev. 0) and "Methodology for Identification of Testing to Conduct on Type A and Industrial Packagings" (WMTS-IP/7A-003, Rev. 0) are approved.

If you have any questions, please contact me at 301-903-5078.

Sincerely,

Michael E. Wangler

Michael E. Wangler, Director
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CONTENTS

CONTENTS, cont

LIST OF TABLES

LIST OF TERMS

cm	centimeter
DOT	U.S. Department of Transportation
DOT Type A	DOT Type A Packagings
h	hour
in.	inch
IP	industrial packagings
kg	kilogram
kPa	kilopascal
lb	pound
LSA	low specific activity
m	meter
mrem	millirem
POP	performance-oriented packaging
ft	foot

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METHODOLOGY FOR IDENTIFICATION OF TESTING TO CONDUCT ON TYPE A AND INDUSTRIAL PACKAGINGS

1.0 INTRODUCTION

1.1 PURPOSE

This document furnishes knowledge and methods for determining how to demonstrate compliance with the U.S. Department of Transportation (DOT) packaging testing requirements for Type A packagings (DOT Type A) and Industrial Packagings (IP). The primary emphasis is on the requirements identified in Title 49 of the *Code of Federal Regulations* (49 CFR) 173.411, “Industrial packagings,” 173.412, “Additional design requirements for Type A packages,” 173.461, “Demonstration of compliance with tests,” 173.462, “Preparation of specimens for testing,” 173.465 “Type A packaging tests,” 173.466, “Additional tests for Type A packagings designed for liquids and gases,” and 178.350, “Specification 7A; general packaging, Type A.” These sections of the regulations identify the testing requirements and methods for demonstration of compliance. This document does not provide guidance for the testing of fissile materials packagings.

1.2 SCOPE

This document identifies methods for determining how to test packagings for regulatory compliance with DOT Type A and IP packaging testing requirements. Users of this document will learn to:

1. Identify applicable packaging tests for the material to be shipped based on radiological and physical characteristics. (i.e., low specific activity [LSA], Type A, solid, liquid, or gas).

2. Identify how to select approved methods for use in demonstrating compliance with the required tests.

3. Understand the importance of the pass/fail criteria in demonstrating compliance with the required tests.

4. Review design features to determine how to apply the test requirements to the packaging safety features.

5. Identify acceptable test facilities.

6. Identify the number of tests of each type to conduct.

7. Identify the type of test to conduct.

8. Identify the number of test units needed.

1.3 APPROACH

This guidance document is based upon the premise that while DOT Type A and IP package testing are succinctly defined requirements, they are not clearly defined activities. Compliance not only requires comprehension/understanding of the requirements, but also the intent of the requirements. The intent of the test requirements is to show that the package's safety features will function properly under the identified conditions. The conditions are intended to simulate rough handling during transportation. The conditions are not intended to simulate accident conditions. This document, using discussions and examples, tries to provide an understanding of the requirements so that the user can look at a packaging and determine how to adequately demonstrate compliance.

1.4 DEFINITIONS

The meaning of the terms in this document follows the definitions identified in 49 CFR 100 through 185. The following definitions identify the usage of specific terms not covered in the regulations. Readers should be familiar with the definitions specifically provided in 49 CFR 173.403, "Definitions."

Material custodian—the person assigned responsibility for custody of the material.

Package (or packaging) engineer—a person understanding the packaging portions of the transportation regulations and having specialized knowledge about packagings for hazardous materials.

Shipper—a person signing the certification statement on the shipping papers.

Specialist (or transportation specialist)—a person having detailed knowledge about transportation regulations and package selection for hazardous materials.

1.5 RESPONSIBILITIES

1.5.1 Identification of Split in Responsibilities for Meeting Packaging Requirements

The tester of a Type A packaging is assuming the responsibilities identified for the shipper and/or the manufacturer in the DOT regulations. The tester of an IP is assuming the responsibilities identified for the shipper. The DOT regulations do not identify responsibilities for a manufacturer of an IP. The responsibilities for ensuring a package meets all regulatory requirements at the time of shipment, including testing, are placed on the shipper. The tester of

IP and Type A packagings must identify to the shipper/manufacturer how and what testing was conducted and the effects of that testing on the surrogate load and packaging. The packaging user must be made aware of all packaging requirements not met when the packaging is provided. For example, evaluation of the changes in radiation levels at the surface of the packaging that results from changes in the packaging and load due to testing.

The requirements identified in 49 CFR 173, Subpart I, “Class 7 (radioactive) materials,” come into play after a hazardous material for shipment is identified and classified as radioactive material. Subpart I identifies the applicable requirements that the radioactive material packaging must meet to be shipped in compliance with the DOT regulations.

Table 1-1 identifies the radioactive material packaging design and documentation requirements for low-end radioactive material shipments, and discusses the complex sharing of responsibility that can result when designing and fabricating a package. The first item in Table 1-1 applies only to Specification 7A; general packaging, Type A per 49 CFR 178.350, “Specification 7A; general packaging, Type A.” However, the requirements are a good business practice for all low-end radioactive material packagings. The remaining items apply to the packaging types identified in the “Comments” column of the table.

All responsibilities identified in 49 CFR, Subpart I, are established for the offeror (shipper). The subpart does not identify responsibilities for other parties. The subpart does identify that Subparts A and B are also applicable to the design of radioactive material packagings. To clarify responsibilities for the packaging, attention is directed to 49 CFR 173.1, *Purpose and scope*, (c), which reads as follows: “*When a person other than the person preparing a hazardous material for shipment performs a function required by this part, that person shall perform the function in accordance with this part*.” This section identifies that when you conduct a part of the packaging design and fabrication process, that you are assuming the responsibilities associated with that packaging identified as the responsibility of the offeror (shipper). To avoid problems, the requirements that were considered when designing a packaging should be identified, along with documentation establishing how the requirements are met or not met.

Table 1-1. Packaging Responsibilities Matrix.

REQUIREMENT	OFFEROR/SHIPPER[1]	MANUFACTURER[2]	TESTER[3]	DESIGNER[4]	COMMENTS
49 CFR 178.350, Specification 7A; general packaging, Type A	When a package built to this specification is used for shipment as a Type A package, the offeror must verify that all applicable package requirements are met and must posses all the documentation required by 49 CFR 173.415(a).	When a manufacturer meets the DOT definition of manufacturer and builds a package to this specification, the requirements identified in 49 CFR 178.2 and 178.3 must be met. In meeting the requirements of 49 CFR 178.2, the manufacturer must identify any applicable requirements that are not met at the time the package is provided.	When a package built to this specification is tested, the testing process, the results of the testing, and the evaluation of performance must be documented.	When designing a packaging to this specification, it is the responsibility of the designer to assure that all of the design requirements identified in 49 CFR 173 are considered. Note that not all the applicable design requirements are specifically identified in 49 CFR 178.350. When the requirements are applicable to the material to be shipped in the package, they must be met and documented. It is recommended that when a requirement is not applicable, that this determination also be documented.	**Specification 7A Type A** Note that the wording of the regulations does not clearly define who is specifically responsible for what activity of the design and manufacturing process. This can result in errors during the design, fabrication process, and use. Interface between organizations and the information that moves across those interfaces should clearly be defined. Note that for the manufacturer, 49 CFR 178.2 is a requirement, and that they assure that this is accomplished for packagings where they meet the DOT definition of manufacturer.
49 CFR 173.403, Definitions	Understanding the definitions in this section is critical to the offeror complying with the packaging regulations.	For a manufacturer that meets the DOT definition of manufacturer, under-standing the definitions in this section is critical to a complying with the packaging regulations. Where the manufacturer is building to a design provided by others, that understanding is not of critical importance.	Understanding the definitions in this section is critical to the tester complying with the packaging regulations.	Understanding the definitions in this section is critical to the designer complying with the packaging regulations.	**Strong-tight, IP-1, IP-2, IP-3, and Specification 7A Type A** The definitions provide guidance about the meaning of key words used in the regulations. Failure to review the definitions could result in a regulatory violation.

REQUIREMENT	OFFEROR/SHIPPER[1]	MANUFACTURER[2]	TESTER[3]	DESIGNER[4]	COMMENTS
49 CFR 173.410, General design requirements	The offeror is responsible to assure that the package is designed to meet the packaging requirements applicable to the load being shipped.	The manufacturer is responsible to fabricate the packaging to the applicable design. For Specification 7A Type A packagings, any applicable requirements not met at the time of transfer must be identified in the notification (see 49 CFR 178.2[c]). Providing that information for other packagings is good business practice.	None.	The designer is responsible to assure that the package is designed to meet the packaging requirements applicable to the design-based load. Where a user-based load has not been identified, identify the base load assumed for the design. Identify, where known, the materials that are not compatible with the materials of construction.	**Strong-tight, IP-1, IP-2, IP-3, and Specification 7A Type A** When a package is designed, fabricated, tested, and evaluated by more than one organization, care must be exercised to assure interfaces and information exchanges are clearly defined and implemented.
49 CFR 173.411, Industrial packagings	The offeror is responsible to assure that the package is designed, fabricated, and where mandatory, tested to meet the packaging requirements applicable to the load being shipped. In addition, the offeror must meet the recordkeeping requirements.	The manufacturer is responsible to fabricate the packaging to the applicable design. Based on assumed responsibility, provide documentation that the package meets the design requirements for materials and methods of construction.	Conduct applicable tests and document the performance. Based on assumed responsibility, provide documentation to manufacturer/offeror to meet requirement for retention of records. Be sure to identify and document any requirements not completed.	The designer is responsible to assure that the package is designed to meet the packaging requirements applicable to the packaging type and design load. The design must consider pass/fail criteria. Based on assumed responsibility, provide documentation to manufacturer/offeror to meet requirement for retention of records.	**IP-1, IP-2 and IP-3**
49 CFR 173.412, Additional design requirements for Type A packages	The offeror is responsible to assure that the package is designed, fabricated, and tested to meet the packaging requirements applicable to the load being shipped. In addition, the offeror must meet the recordkeeping	The manufacturer is responsible to fabricate the packaging to the applicable design. Based on assumed responsibility, provide documentation that the package meets the design requirements for	Conduct applicable tests and document the performance. Based on assumed responsibility, provide documentation to manufacturer/offeror to meet requirement for retention of records. Be sure to identify and	The designer is responsible to assure that the package is designed to meet the packaging requirements applicable to the design load. The design must consider pass/fail criteria. The designer needs	**IP-2, IP-3, and Specification 7A Type A** The types of documents useful in supporting that a packaging meets design requirements are identified in 49 CFR 173.403, definitions.

REQUIREMENT	OFFEROR/SHIPPER[1]	MANUFACTURER[2]	TESTER[3]	DESIGNER[4]	COMMENTS
	requirements.	materials and methods of construction. Conduct applicable tests and document the performance. Based on assumed responsibility, provide documentation to manufacturer/offeror to meet requirement for retention of records. Be sure to identify and document any packaging requirements not completed.	document any packaging requirements not completed.	information on the design-based load. This information is needed to select the proper design criteria. Based on assumed responsibility, provide documentation to manufacturer/offeror to meet requirement for retention of records.	
49 CFR 173.415, Authorized Type A packages	This regulation identifies to the offeror that a package built to 49 CFR 178.350 can be used to ship Type A quantities of radioactive material. It identifies a responsibility to have, at the time of shipment and retain for one-year, documentation that shows the testing, construction methods, packaging design, and materials of construction comply with the specification.	Based on assumed responsibility, the manufacturer should document that the construction methods, packaging design, and materials of construction are as identified by the design documentation.	Based on assumed responsibility, provide documentation of any testing conducted to demonstrate the ability of the design or materials of construction to meet identified performance requirements.	Based on assumed responsibility, the designer should provide documentation to show that the packaging design uses a design, construction methods, and materials of construction that result in compliance with the applicable requirements for the design-based load.	**IP-2, IP-3, and Specification 7A Type A** When the package is used, the offeror/shipper must have in their possession documentation that shows the package meets all applicable requirements. All organizations involved in the design and testing should transmit all needed information between each other. Note that there is considerable interplay between the load and the design requirements. Just because the package meets the requirements with one load, does not mean it will met the

REQUIREMENT	OFFEROR/SHIPPER[1]	MANUFACTURER[2]	TESTER[3]	DESIGNER[4]	COMMENTS
					requirements for another. Changes in the physical, chemical, and radiological characteristics can result in noncompliance.
49 CFR 173.441, Radiation level limitations	The offeror must assure that the package meets the radiation level limitations at the time of shipment.	No responsibility for manufacturer.	No responsibility for tester.	Based on assumed responsibility, the designer should provide documentation to show that the packaging design uses a design, construction methods, and materials of construction that result in compliance with the applicable radiation level limitations for the design-based load and type of shipment (exclusive use, non-exclusive use).	**Strong-tight, IP-1, IP-2, IP-3, and Specification 7A Type A** These requirements are both operational controls and design requirements. This is an area where the interaction between the design and the load are critical. When a generic load is used for the design it should be clearly identified in the design documentation. The radioactive material used should be identified as to the isotopes and distribution within the load.
49 CFR 173.442, Thermal limitations	The offeror must assure that the package meets the thermal limitations at the time of shipment. In addition, the offeror must assure the package integrity will not be impaired by the thermal load.	No responsibility for manufacturer.	No responsibility for tester.	Based on assumed responsibility, the designer should provide documentation to show that the packaging design uses a design, construction methods, and materials of construction that result in compliance with the applicable thermal level limitations for the design-	**Strong-tight, IP-1, IP-2, IP-3, and Specification 7A Type A** These requirements are both operational controls and design requirements. This is an area where the interaction between the design and the load are important. Because the quantity of radioactive

REQUIREMENT	OFFEROR/SHIPPER[1]	MANUFACTURER[2]	TESTER[3]	DESIGNER[4]	COMMENTS
				based load. The documentation should cover both package integrity and surface temperatures for the design-based load and type of shipment (exclusive use, non-exclusive use).	material is restricted, the thermal limits are normally not a problem. However, the design could result in problems if the packaging is designed such that it provides significant insulation.
49 CFR 173.461, Demonstration of compliance with tests	The offeror must assure that the package was tested and evaluated in accordance with the applicable requirements of this section. In addition, the offeror must assure they have documentation of the testing and evaluation in their possession.	No responsibility for manufacturer.	Based on assumed responsibility, provide documentation of any testing and evaluations conducted to demonstrate the ability of the package to meet applicable requirements. The documentation should identify the methodology used as well as the results. Note that the results should include documentation of the damage to the package and movement of the load. This information is needed to determine changes in radiation levels at the surfaces of the package when different payloads are shipped.	Based on assumed responsibility, the designer should document all evaluations conducted to show compliance with design and test requirements applicable to the package. The documentation should identify the methodology used as well as the evaluation results.	**IP-2, IP-3, and Specification 7A Type A** The method or methods chosen for demonstrating compliance will influence the number of organizations involved. The lead organization should assure that the interface between organizations is identified and that the correct information is passed between the organizations.
49 CFR 173.462, Preparation of specimens for testing	The offeror must assure that the package was prepared for testing and evaluated in accordance with the applicable requirements of this	No responsibility for manufacturer.	Based on assumed responsibility, provide documentation of the conditions identified for the packagings tested or evaluated for ability to	No responsibility for designer.	**IP-2, IP-3, and Specification 7A Type A** The method or methods chosen for demonstrating compliance will influence

REQUIREMENT	OFFEROR/SHIPPER[1]	MANUFACTURER[2]	TESTER[3]	DESIGNER[4]	COMMENTS
	section. In addition, the offeror must assure they have documentation of the conditions identified in their possession.		meet test requirements. The documentation should identify the conditions found or for evaluations assumed.		the number of organizations involved. The lead organization should assure that the interface between organizations is identified and that the correct information is passed between the organizations. Watch that this step occurs when the package is prepared for testing by one organization then sent to another organization to be tested.
49 CFR 173.465, Type A packaging tests	The offeror must assure that the tests applicable to the packaging type and load to be shipped have been conducted and documented. The offeror must have a copy of the documentation in their possession at the time of shipment.	No responsibility for manufacturer.	Based on assumed responsibility, the tester must conduct and document the tests applicable to the packaging type and load to be shipped. The documentation should identify the test conditions and results of the test, not just the overall pass/fail evaluation. It should be clearly identified if all or part of the test results is evaluated.	If the designer assumes the responsibility for accomplishing the tests through a method other than testing, they must provide the documentation of the methods used and the results. The documentation must cover how pass/fail criterion is met.	**IP-2, IP-3, and Specification 7A Type A** The method or methods chosen for demonstrating compliance will influence the number of organizations involved. The lead organization should assure that the interface between organizations is identified and that the correct information is passed between the organizations. An area that is easily overlooked is the evaluation of changes in radiation levels.

REQUIREMENT	OFFEROR/SHIPPER[1]	MANUFACTURER[2]	TESTER[3]	DESIGNER[4]	COMMENTS
49 CFR 173.466, Additional tests for Type A packagings designed for liquids and gases.	For packages that contain Type A quantities of liquids or gases, the offeror must assure that the ability of the packaging to meet these additional tests has been verified and documented. The offeror must have a copy of the documentation in their possession at the time of shipment.	No responsibility for manufacturer.	Based on assumed responsibility, the tester must conduct and document the tests applicable to the packaging type and load to be shipped. The documentation should identify the test conditions and results of the test, not just the overall pass/fail evaluation. It should be clearly identified if all or parts of the test results are evaluated.	If the designer assumes the responsibility for accomplishing the tests through a method other than testing, they must provide the documentation of the methods used and the results. The documentation must cover how pass/fail criterion is met.	**Specification 7A Type A** The method or methods chosen for demonstrating compliance will influence the number of organizations involved. The lead organization should assure that the interface between organizations is identified and that the correct information is passed between the organizations.
49 CFR 173.468, Test for LSA-III material	For packagings that are dependent on the material meeting LSA-III criteria to pass the applicable packaging requirements, the offeror must have the documentation of the LSA-III testing in their possession at the time of shipment.	No responsibility for manufacturer.	For packaging tester, if packaging performance is dependent of the load meeting LSA-III requirements, identify that condition in the packaging testing documentation. For tester of LSA-III material, based on assumed responsibility, document the conditions and results of LSA-III testing.	For the packaging designer, if the package is designed based on a load that meets the LSA-III requirements, identify that limitation in the design documentation.	**LSA-III material when shipped in IP-2 or IP-3 as applicable** The method or methods chosen for demonstrating compliance will influence the number of organizations involved. The lead organization should assure that the interface between organizations is identified and that the correct information is passed between the organizations.

REQUIREMENT	OFFEROR/SHIPPER[1]	MANUFACTURER[2]	TESTER[3]	DESIGNER[4]	COMMENTS
49 CFR 173.469, Test for special form Class 7 (radioactive) materials	For packages that are dependent on the load meeting special form criteria to pass the applicable packaging requirements, the offeror must have the documentation of the special form design in their possession at the time of shipment.	No responsibility for packaging manufacturer.	For packaging tester, if packaging performance is dependent of the load meetings special form requirements, identify that condition in the packaging testing documentation. For tester of special form material, based on assumed responsibility, document the conditions and results of special form testing.	For the packaging designer, if the package is designed based on a load meeting the special form requirements, identify that limitation in the design documentation.	**Specification 7A Type A** The method or methods chosen for demonstrating compliance will influence the number of organizations involved. The lead organization should assure that the interface between organizations is identified and that the correct information is passed between the organizations.
49 CFR 173.474, Quality control for construction of packaging	Prior to first use of a packaging, the offeror needs to verify the packaging meets the quality of design and construction requirements. In addition the effectiveness of shielding, containment, and when required, the heat transfer characteristics, are within the specified design limits of the packaging.	Based on assumed responsibility, the manufacturer should document any activities conducted to verify the performance ability of the packaging.	No responsibility for packaging tester.	No responsibility for packaging designer.	Strong-tight, IP-1, IP-2, IP-3, and Specification 7A Type A

49 CFR 173, ‘Shippers—general requirements for shipments and packagings,” *Code of Federal Regulations*, as amended.

49 CFR 178, “Specifications for packagings,” *Code of Federal Regulations*, as amended.

[1] Offeror/shipper – the organization preparing a package for shipment and tendering it to a carrier for transport. For low-end radioactive materials packagings, this organization is most often the organization meeting the definition of manufacturer identified in 49 CFR 178.2.

[2] Manufacturer – the organization(s) producing packagings for use in assembling a package meeting DOT design requirements for a packaging type. This organization may or may not be the manufacturer as identified in 49 CFR 178.2.

[3] Tester – the organization that is conducting packaging testing to verify compliance with DOT-identified design requirements for the packaging type.

[4] Designer – the organization that is preparing the packaging design that the manufacturer will build the packagings to match.

1.6 TESTING PROCESS

The following is an outline of the typical sequence of activities conducted by a testing and evaluation organization when a package is submitted for test and evaluation.

The initial step is to obtain the design information and the documentation showing compliance with the regulatory design requirements. This information is reviewed to verify

- that the load classification is correct,
- that based on the load classification an acceptable package type was selected, and
- that the correct design requirements were implemented, based on the package type.

When it is known that the packaging has been appropriately designed for the radiological and physical characteristics of the material to be transported (i.e., IP-1, IP-2, IP-3, or Type A), the test requirements applicable to the package are identified. With the test requirements in mind, the package design is reviewed to determine the weakest areas in the safety features. The features being looked at are those that provide or protect the containment boundary, and those that provide or protect the radiation shielding.

Based on the design review, a preliminary listing is made that identifies the proposed number of tests and package orientations to use within a test type. The preliminary list is then reviewed in conjunction with design information to see if the proposed test can be eliminated on the basis of available information. Once the tests are identified, the number of packagings needed is determined. A new packaging can be used for each test. The regulations, however, permit the use of a single package for demonstrating compliance with the test requirements. An additional test on a package can result in failure due to cumulative damage; therefore, tradeoffs are made when determining the number of packages to use.

After identifying the type and number of tests to be conducted, a review is made to identify test facilities. With a test facility identified, a test plan is developed. The test plan identifies

- test facilities
- tests to be conducted
- test equipment needed
- general test procedures
- specific implementation details for the general test procedures
- test pass/fail criteria
- surrogate loads
- package orientations
- proposed package markings and identification
- proposed test sequence.

The test plan also provides forms for use in documenting the initial and final conditions of the test specimens and results of preliminary evaluations.

Test specimens are obtained from the test sponsor. The specimens are inspected and marked. Tests are conducted and documented. The test results are reviewed and evaluated, and a test report is prepared.

2.0 TESTING REQUIREMENTS

The need to test IP and DOT Type A packagings is identified in 49 CFR 173, Subpart I. The testing requirements and pass/fail criteria applicable to IP packagings are identified in 49 CFR 173.411, “Industrial packagings.” In addition to identifying the need to test, the section identifies the need to retain documentation of the testing and evaluations conducted to demonstrate compliance. “Except for IP-1 packagings, each offeror of an industrial package must maintain on file for at least one year after the latest shipment, and shall provide to the Associate Administrator for Hazardous Materials Safety on request, complete documentation of tests and an engineering evaluation or comparative data showing that the construction methods, packaging design, and materials of construction comply with that specification.”

The testing requirements and pass/fail criteria applicable to DOT Type A packagings are identified in 49 CFR 173.412, “Additional design requirements for Type A packages.” The need to retain documentation of the testing and evaluations conducted to demonstrate compliance is identified in 49 CFR 173.415, “Authorized Type A packages.” “Each offeror of a Specification 7A package must maintain on file for at least one year after the latest shipment, and shall provide to DOT on request, complete documentation of tests and an engineering evaluation or comparative data showing that the construction methods, packaging design, and materials of construction comply with that specification.”

The pass/fail criteria for passing the test requirements is that the packaging must prevent “…loss or dispersal of the radioactive contents; and … a significant increase in the radiation levels recorded or calculated at the external surfaces for the condition before the test.”

The acceptable methods for demonstrating compliance with the test requirements are identified in 49 CFR 173.461, “Demonstration of compliance with tests.” In 49 CFR 173.462, “Preparation of specimens for testing,” requirements for preparation of the packaging for testing are provided. Documentation of the pretest requirements is required. The requirements should be considered regardless of the method(s) used to demonstrate compliance with the test requirements. More information on these requirements will be provided later in this document.

The actual tests that the packagings are to be subjected to, along with the facilities and equipment to be used when conducting the tests, are identified in 49 CFR 173.465, “Type A packaging tests.” Some additional tests applicable to DOT Type A packagings for liquids and gases are identified in 49 CFR 173.466, “Additional tests for Type A packagings designed for liquids and gases.” Note that if a package is tested for shipment of special form material, the need for documentation of compliance of the material to special form should be identified to the user.

3.0 IDENTIFYING APPLICABLE TESTS

The number and type of tests that must be conducted on the packaging are dependent on the radiological characterization and the physical form of the load. In addition, for some tests the conditions are varied based on the mass of the package and on the physical form of the load, the package shape and the materials of construction. Either the actual load or an assumed load can be used to identify the tests to conduct. When an assumed load is used, identify the characteristics of the load.

3.1 LOAD CHARACTERIZATION

Details on characterization of a load and selecting the proper packaging can be found in HNF-SD-TP-TI-006, *Documentation and Verification Required for Type A Packaging Use* (Kelly and O'Brien 2001). When necessary, contact the material custodian to obtain information on the load. After the load is characterized and the quantity to be placed in the package determined, the load can be classified and a proper packaging type selected. Once the packaging type is identified, the test requirements applicable to the package type can be identified. This document only covers the requirements for four radioactive material packaging types. The packaging types and their test requirements are identified in Table 3-1.

Table 3-1. Test Requirements.

Material Classification	Package Type	Required Tests
LSA-I/SCO-I	IP-1	none
LSA-II/SCO-II	IP-2	49 CFR 173.465(c), Free drop test
		49 CFR 173.465(d), Stacking test
LSA-III/SCO-III	IP-3	49 CFR 173.465(c), Free drop test
		49 CFR 173.465(d), Stacking test
Type A quantity (solids)	Specification 7A Type A (for solids)	49 CFR 173.465(a), application of tests
		49 CFR 173.465(b), Water spray test
		49 CFR 173.465(c), Free drop test
		49 CFR 173.465(d), Stacking test
		49 CFR 173.465(e), Penetration test
Type A quantity (liquids and gases)	Specification 7A Type A (for liquids and gases)	49 CFR 173.465(a), application of tests
		49 CFR 173.465(b), Water spray test
		49 CFR 173.465(c), Free drop test
		49 CFR 173.465(d), Stacking test
		49 CFR 173.465(e), Penetration test
		49 CFR 173.466(a), additional tests
		49 CFR 173.466(a)(1), Free drop test
		49 CFR 173.466(a)(2), Penetration test

49 CFR 173, "Shippers—general requirements for shipments and packagings," *Code of Federal Regulations*, as amended.

3.2 TEST VARIATIONS

For the tests identified in Table 3-1 some portions of the test are varied based on packaging features such as mass, shape, or materials of construction. The following subsections identify the variations and the basis for their application. Note that for IP-1 packaging, no tests are required; however, the packaging must be shown as meeting the requirements of 49 CFR 173.410, "General design requirements." Refer to Section 6.0 for guidance on the verification of design requirements by testing.

3.2.1 IP-2 and IP-3 Testing Variations

3.2.1.1 Free Drop. For IP-2 and IP-3 packagings the free drop height is based on the mass of the package (packaging plus contents). If the packaging is rectangular, constructed of fiberboard or wood, and has a mass of 50 kg (110 lb) or less, then a separate specimen must be subjected to a free drop onto each corner from a height of 0.3 m (1 ft). If the packaging is cylindrical, constructed of fiberboard, and has a mass of 100 kg (220 lb) or less, a separate specimen must be subjected to a free drop onto each of the quarters of each rim from a height of 0.3 m (1 ft).

3.2.1.2 Stacking Test. For IP-2 and IP-3 packagings the stacking test varies based on the mass of the package or with the projected top surface area of the package. The basis of the selection of the compressive load should be documented.

3.2.2 DOT Type A Testing Variations

3.2.2.1 Free Drop. For Type A packagings the free drop height is based on the mass of the package (packaging plus contents). In addition, if the packaging is rectangular, constructed of fiberboard or wood, and has a mass of 50 kg (110 lb) or less, then a separate specimen must be subjected to a free drop onto each corner from a height of 0.3 m (1 ft). If the packaging is cylindrical, constructed of fiberboard, and has a mass of 100 kg (220 lb) or less, a separate specimen must be subjected to a free drop onto each of the quarters of each rim from a height of 0.3 m (1 ft).

If the packaging is for liquids or gases an additional set of drop conditions are established. The packaging containment and shielding must be verified to be capable of passing a 9 m (30-ft) drop.

3.2.2.2 Stacking Test. For Type A packagings, the stacking test varies based on the mass of the package or with the projected top surface area of the package. The basis of the selection of the compressive load should be documented.

3.2.2.3 Penetration Test. For a Type A packaging for liquids or gases an additional set of penetration drop conditions are established. The packaging must be capable of withstanding a penetration test conducted from a height of 1.7 m (5.5 ft).

3.3 DETERMINING WHICH SPECIFIC TESTS TO APPLY

The specific tests to apply to a packaging cannot be determined until the design and the gross mass are known. An assumed design can be used for the initial selection and development of a test plan and procedures, but must be confirmed prior to conducting the tests.

The following subsections discuss identification of applicable tests for the packaging types that are identified in Table 3-1.

> NOTE: Section 4.0 provides guidance for demonstrating compliance. Section 5.0 provides guidance for determining how to apply tests. Section 6.0 provides guidance for verification of design requirements by testing.

3.3.1 IP-2 Packages

The initial determination of the applicable tests for an IP-2 package is based on the load classification. If the load is classified as LSA-II/SCO-II then an IP-2 packaging is acceptable. The basic tests to be conducted on the IP-2 packages are identified in Table 3-1. The tests are a free drop and a stacking test. Note that a package tested to these requirements containing LSA-II liquids or gas must be shipped exclusive use (see 49 CFR 173.427, “Transport requirements for low specific activity [LSA] Class 7 [radioactive] materials and surface contaminated objects [SCO]”).

3.3.1.1 Free Drop. Selection of the test variations is based on the package gross mass. The first determination is of the drop height. The height is based on the gross mass of the package and is determined based on the guidance provided in 49 CFR 173.465(c)(1). After the primary drop height is identified, the need for additional drops is evaluated.

The evaluation for additional tests is based on gross mass, materials of construction, and on physical shape. If the gross mass of the package exceeds 100 kg (220 lb) no additional drop tests are required regardless of materials of construction and shape.

If the package is a cylindrical fiberboard package with a gross mass of 100 kg (220 lb) or less then a separate package must be tested. The test specimen must be subjected to a free drop onto each of the quarters of each rim from a height of 0.3 m (1 ft).

If the packaging is rectangular, constructed of fiberboard or wood, and has a mass of 50 kg (110 lb) or less, then a separate specimen must be subjected to a free drop onto each corner from a height of 0.3 m (1 ft).

3.3.1.2 Stacking Test. Selection of the test variation to apply is dependent on the greater of two possible compressive loads. The two loads to be compared are five times the gross mass of the package and the mass determined by multiplying the vertically projected surface area of the package by 13 kPa (1.9 lb/in.^{2}). For a packaging with an odd shape, determining the exact projected surface area can be difficult. It is acceptable to use a conservative estimate based on the largest horizontal circle or rectangle surface area that hides the package from a top or bottom view.

3.3.2 IP-3 Packages

The applicable tests and variation for IP-3 packages are identified in the same manner as described for IP-2 packages. The basic tests to be conducted on the IP-3 packages are identified in Table 3-1. If the load is classified as LSA-II (containing liquid or gas) or LSA-III then an IP-3 packaging is acceptable. The IP-3 package, however, has some additional design requirements. One of those design requirements is that the package be able to withstand a reduction in external pressure to 25 kPa (3.6 lb/in.^{2}). This requirement is often checked by conducting a pressure test. More will be said about this test in Section 6.2 of this document where methods of testing are discussed.

3.3.3 Type A Packages (Solids)

If the load is classified as Type A quantity of solid material, the first cut at the applicable tests is based on the load classification. The basic tests to be conducted on the Type A packages (for solids) are identified in Table 3-1. The tests are the water spray, free drop, stack, and penetration. Note that a package containing a Type A quantity of liquids or gases requires additional testing (see Section 3.3.4). Note that while required to be conducted, the regulations in 49 CFR 173.461 permit the tests to be evaluated. If an evaluation is used, it must be documented.

3.3.3.1 Water Spray. The water spray is both a test and a conditioning step. Because it is a conditioning step, it is required to be preformed prior to each of the other required tests. Water may be sprayed to all sides of the package at once (simultaneously) or consecutively. Note that while required to be conducted, the regulations in 49 CFR 173.461 permit the tests to be evaluated. If an evaluation is used it must be documented.

3.3.3.2 Free Drop. Selection of the drop height and additional drop requirements are based on the same requirements as for the IP-2 and IP-3 packages. See Section 3.3.1.1 for details. Remember, for Type A packages the package is required to be water sprayed as a conditioning step prior to conducting this test. In addition, if an evaluation is performed, the effect of the water spray test on the package needs to be taken into account.

3.3.3.3 Stacking Test. Selection of the stacking test is based on the same conditions as discussed for the IP-2 and IP-3 packagings. See Section 3.3.1.2 for details. Remember, for Type A packages the package is required to be water sprayed as a conditioning step prior to conducting this test. In addition, if an evaluation is performed, the effect of the water spray test on the package needs to be taken into account.

3.3.3.4 Penetration Test. The need for the penetration test is based on load classification alone. If the package is to contain a Type A quantity of material, this test is applicable. Remember, for Type A packages the package is required to be water sprayed as a conditioning step prior to conducting this test. In addition, if an evaluation is performed, the effect of the water spray test on the package needs to be taken into account.

3.3.4 Type A Package (Liquids and Gases)

Type A packagings for liquids and gases must meet the same requirements as a Type A package for solids. If the load is classified as Type A quantity of solid material, the first cut at the applicable tests are based on the load classification. However, based on the physical form of the load materials, two additional tests must be conducted. The basic tests to be conducted on liquid and gas Type A packages are identified in Table 3-1. The tests are a water spray, free drop, stack and penetration, plus a second free drop and second penetration test. Note that a package tested to these requirements can be used to ship a Type A quantity of solid radioactive material. Selection of testing is based on the same conditions as discussed for the Type A solid packagings. Note there are no variations in the additional test requirements.

4.0 METHODOLOGIES FOR DEMONSTRATING COMPLIANCE

The following section discusses methodologies for demonstrating that the specific test requirements are met. Discussion begins by quoting the regulatory requirement. The quote is followed by a discussion of factors to keep in mind when applying the methodologies to a package.

> 49 CFR 173.461, "Demonstration of compliance with tests."
>
> *(a) Compliance with the design requirements in § 173.412 and the test requirements in §§ 173.465 through 173.469 must be shown by any of the methods prescribed in this paragraph, or by a combination of these methods appropriate for the particular feature being evaluated:*
>
> *(1) Performance of tests with prototypes or samples of the specimens representing LSA-III, special form Class 7 (radioactive) material, or packaging, in which case the contents of the packaging for the test must simulate as closely as practicable the expected range of physical properties of the radioactive contents or packaging to be tested, must be prepared as normally presented for transport. The use of non-radioactive substitute contents is encouraged provided that the results of the testing take into account the radioactive characteristics of the contents for which the package is being tested;*
>
> *(2) Reference to a previous, satisfactory demonstration of compliance of a sufficiently similar nature;*
>
> *(3) Performance of tests with models of appropriate scale incorporating those features that are significant with respect to the under investigation, when*

engineering experience has shown results of those tests to be suitable for design purposes. When a scale model is used, the need for adjusting certain test parameters, such as the penetrator diameter or the compressive load, must be taken into account; or

(4) Calculations or reasoned evaluation, using reliable and conservative procedures and parameters.

(b) With respect to the initial conditions for the tests under §§173.465 through 173.469, except for the water immersion tests, compliance must be based upon the assumption that the package is in equilibrium at an ambient temperature of 38°C (100°F).

Having identified what test must be conducted, it must be decided how to conduct the test on the packaging. Note that 49 CFR 173.461 authorizes four basic methods for demonstrating compliance. Those four basic methods contain variations and the basic methods may be used in combination with each other. This results in a large number of methods from which to select. The first method discussed is actual testing on prototype or sample packagings. The discussion begins with this method not only because it is listed first, but also because the problems that arise in actual testing must be taken into account when using the other evaluation methods. In addition, for small low-cost packagings, testing is likely to be the most economical method.

4.1 GENERAL CONSIDERATIONS

When deciding how to test a packaging, bear in mind there are two pass/fail criteria. First, the test must not result in a loss or dispersal of radioactive material. Loss or dispersal of materials is judged on a qualitative basis. For solids and liquids, a visual inspection is usually conducted for signs of material being released from the package. For gases, the usual method is to check the pressure before and after the testing, watching for a reduction in pressure. This criterion is usually used correctly. However, instances of incorrect use have been observed. For example a package burping at impact, then not leaking can occur. Based on the DOT criteria of no loss or dispersal of radioactive material, this should be judged a failure. Individuals who normally test performance-oriented packagings (POP) have called this a pass. This results from the DOT POP criteria for drum testing that permits a burp at impact so long as the leaking stops (49 CFR 178, "Specifications for packagings"). Remember no loss or dispersal of material is permitted from a package of radioactive materials. Note that a release of material from the packaging can result without a release of radioactive material to the environment. For example, an outer packaging that holds several inner containers can release those containers without those containers releasing the radioactive material to the environment. In this case, while there is no loss of containment, there is a loss or dispersal of radioactive material from the package.

The second criterion is where testers have a tendency to be deficient in evaluating. That criterion requires there not be a significant increase in the radiation level on the surface of the package due to the effects of the test on the package and/or load.

This criterion raises several questions that must be considered. First, what constitutes a significant increase in radiation level? Based on *Regulations for the Safe Transport of*

Radioactive Material 1996 Edition, Requirements No. ST-1 (IAEA 1996), a twenty-percent increase at any surface is significant. This recommendation, however, can result in failure due to increases with little safety significance. For example, the maximum dose rate observed on the package surface prior to testing was 30 mrem/h. The remaining surfaces had dose rates of about a factor of ten less. During testing, as a result of a shifting of the point source contained within the package, the dose rate on one of the other surfaces doubled. Under the IAEA recommendations, this would be judged a failure. Based on the US regulations, the change would be judged insignificant. The new dose rate was still a factor of five less than the maximum pretest dose rate and much less than the 200 mrem/h permitted on an undamaged package.

This brings up the second question. Are increases that remain below the 200 mrem/h permitted on the surface of an undamaged package significant? Not from an exposure standpoint, but from a standpoint of demonstrating regulatory compliance, yes. Note that small increases that stay less than the 200 mrem/h permitted on an undamaged package surface might become significant. Remember that the label applied to the package is based on surface dose rate. A small increase in dose rate could require a different label. If the package shows no signs of external damage, proving it was correctly labeled and/or properly packaged might be difficult. Increases of less than twenty percent that result from testing will be accepted as insignificant even if they would result in a shift above the radiation level requiring a change in the applied label.

Note that during testing it is necessary to collect information on which to base the post-test radiation levels. Changes in the surface of the package should be described both qualitatively and quantitatively in the test documentation. The package should be looked at with the question in mind, "would application of the test at some other point or feature result in a larger increase in radiation level?"

Note when demonstrating compliance by methods other than testing, these two basic pass/fail criteria apply and must be addressed.

4.1.1 Testing

Testing activities require loading the package as it will be loaded for shipping, and subjecting the package to the identified test conditions. Changes in the package are evaluated against the identified criteria to determine if the package passes or fails. Determining how to apply the tests to a package requires a lot of consideration. Determining if the package passes or fails is usually not difficult. As stated previously, a visual indicator is usually selected for loss or dispersal of material. Changes in radiation levels can be shown by actual radiation measurements, or by measuring the damage to the packaging and calculating the changes in radiation levels. Locating a test target may present some difficulties if the package is large, heavy, or if it is made from an unyielding material.

4.1.2 Reference a Previous Test

Referencing a previous, satisfactory demonstration of compliance requires caution. One cannot just look at the basic packaging that provides containment and declare by comparison that the second package will also pass. For example, consider a drum tested for shipping a load of uniformly distributed radioactive material such as contaminated clothing. Now compare that drum to one with the same gross mass, but the new load is now a point source centered in the drum. For the water spray test, if the drums and drum closures are identical and keep out all water arguing that the test is passed by comparison is acceptable. However, if the closure design is different, then some argument that shows acceptability of the difference is needed.

For the penetration test, a comparison is most likely to be accepted if the drums are of an identical design and there was little damage from the penetration test. However, if one of the drums has thinner walls, some additional evaluation may be needed to show the damage does not result in a significant radiation level increase due to the change in distance from the surface to the source. In addition, some argument about the ability of the penetration bar centering device to not affect the forces of the penetration bar hitting the targeted area may be required.

For the compression test, if the drums are identical, a comparison that points out that they are identical and compressed by the same force should be adequate. If however the compression test depended on the load to pass, then some discussion that shows that the two loads perform the same under the test would be required.

Demonstrating the drop test by comparison will require a lot of effort. It will be necessary to show that the loads will resist the forces of the drop test and stress the drum in essentially identical fashion. If this can be shown, then it will be necessary to show that the damage to the drum, coupled with movement of the source within the drum, does not result in a significant increase in radiation levels at the surface of the package. Without testing information, determining the motion of the source within the packaging will require some evaluation to determine how much the source moves. A no loss or dispersal of material comparison will depend on the physical form of the material in the two loads. If the original test was conducted with fine particulate material challenging the closure, then the second drum can be passed if it can be shown that the material that challenges the gasket is no finer. Watch for small differences in the package. For example, the original drum may contain a plastic bag that is needed to pass the no loss or dispersal of material criteria. If the drum being compared does not have a bag, then some other method is needed to demonstrate that there will be no loss or dispersal of material.

4.1.3 Tests with Models

Tests conducted using models of the actual packaging is permitted. When a model is used for testing care must be taken that the model reproduces all features that can result in failure during testing. When a scale model is tested, the scaling techniques used must be documented as acceptable. The documentation must identify the precautions necessary for the scaling technique to accurately predict the behavior of the full size packaging. Scale model testing of closures is not recommended. If a model of the closure is used, the leak detection method must be properly matched with the model to assure an accurate prediction of performance. Evaluation methods must be benchmarked. Without benchmarking, the test will have little value. When evaluating changes in radiation levels, remember to use appropriate scaling that is based on the model and damage observed.

4.1.4 Calculations or Reasoned Evaluation

Calculations and reasoned evaluations may be used rather than testing. The calculations used should be tied to an accepted industry standard or be readily acceptable. When using calculations and reasoned evaluations, the method tends to focus on a particular feature of the packaging. One must be careful to look at all features of the packaging and determine when it is necessary to combine information from separate calculations and evaluations into a whole picture. For example, calculations of bending damage to the packaging need to be combined with calculations of source movement in order to determine changes in radiation levels on the surface of the package.

Calculations and reasoned evaluations are easiest for the compression and penetration tests. With the compression test, be careful to look at where the compression forces are applied. Remember that the regulation identifies a uniformly distributed load. The intent is that the package be able to withstand other packagings being placed on top. In general, during transportation there is no guarantee that the items placed on the top will be of any particular size. Therefore, the uniform load represents a distributed load.

For most packagings, calculations and reasoned evaluations will be difficult for drop testing. Even with the simplest package, setting up a calculation that deals accurately with the dynamics of a drop test is difficult. The analysis needs to be performed by a qualified and experienced analyst who understands how to properly model the impacts of the drop and its effects on the package. When calculations are used for the drop test, it is preferable to have a benchmarked evaluation method.

In many cases, a reasoned evaluation can handle the water spray test. Care needs to be taken if the water can wet surfaces whose properties change when wetted.

4.1.5 Combination of Methods

Combining methods works well for many packagings. For example, the water spray test must be conducted prior to each test. When the water will not effect the performance of the packaging during other tests, conduct the test once. Then use a reasoned evaluation for the pre-test requirement. For some packagings, the initial water spray test can be completed by comparison to a similar packaging. When deciding how to proceed consider the cost involved. If the package is small and cheap, conducting all tests will most likely be cost effective. When the package is expensive then it may be more cost effective to conduct a minimum of tests and combine them with other methods.

For the drop test requirement, at least one drop is recommended. This recommendation is based on the observation that during testing it is common for the unanticipated to occur. For example, consider a top down drop of a drum-based package. It is likely that if calculations were used to conduct the test that all energy would be considered to act in the direction of the drop. In actual testing, some energy is often transferred into motion in another direction. For example, a drum might skid sideways. The effects of the skid might well be overlooked. In an actual test, a feature on the lid of the drum was ripped loose resulting in a loss or dispersal of material. In other instances, parts that are unlikely to be considered, unless considerable time and effort are spent on the evaluation, have resulted in failures. Low cost calculations are often conservative. Overly conservative calculations can result in rejecting an acceptable packaging.

5.0 DETERMINING HOW TO APPLY TESTS

Note that the purpose of the testing is to show that the package design can withstand the identified test. Look at the design for weaknesses, if something is observed that is likely to result in failure, bring it to the attention of the designer. Many package designers tend to think only of the forces that the package must withstand due to the static load. Others add consideration of the dynamic forces of the load during transportation. They do not always remember to take into account the dynamic forces that occur during testing.

Also, there is a tendency to consider only conventional orientations when looking at a package striking an object or struck by an object. During testing, the forces are to be directed at the weakest points of the safety features being evaluated. For example, a package submitted for testing was designed with an impact limiter to provide the package with protection during drops. During the pretest design review, a weakness was identified in the impact limiter. The design was such that the package, when oriented top down, provided no protection under the lid. The limiter was connected only to the package body. Dropping the package top down would result in all forces from the load and the lid being transmitted to the closure bolts. The closure had not been designed to handle the resulting forces. When the flaw was pointed out to the designer, a modification was made to the impact limiter that resulted in the package being able to meet the test requirements.

When applying the tests there are many features of the package that influence the testing decision. Table 5-1 identifies many of features and associated characteristics to keep in mind when determining the number of tests required and how to apply them.

Table 5-1. Characteristics to Consider when Conducting Tests.

Item	Package Feature	Characteristics
1.	Shape of package	Sphere, cube, rectangular parallel piped, parallel piped, cylindrical, multifaceted
2.	Materials of construction	Wood, plastic, fiberboard, steel, aluminum, glass, and other combinations
3.	Methods of construction	Glued, welded, stapled, nailed, screwed, taped, formed, molded, combinations
4.	Mass of package	Weight of package and load together
5.	Single packaging	Containment, or containment and shielding
6.	Combination packaging	Containment/multiple containment, plus supporting packagings such as dunnage, shielding
7.	Physical dimensions of the package	Length, width, height, diameter, volume, other
8.	Aspect ratio of the package	Smallest area to largest perpendicular distance
9.	Physical dimensions of inner packagings	Length, width, height, diameter, volume, other
10.	Location of center of gravity of package	Center of gravity of packaging plus load
11.	Impact limiters	Used/not used, how attached, effects on the distribution of forces
12.	Mass of the load	Weight of load
13.	Center of gravity of the load	Center of gravity of load with and without considering dunnage or packaging
14.	Density of load	Mass per unit volume
15.	Physical dimensions of the load	Size of total load, size of individual units making up load
16.	Physical form of load	Fine particles, large particles, objects, large objects, and combinations
17.	Physical state of the load	Solid, liquid, gas, changes in state during transportation, changes in state over applicable temperature range
18.	Dunnage in package	Solid material, blocking and bracing, lose fill, internal structures
19.	Chemical characteristics of the load	Acidic, basic, corrosive, organic
20.	Closures	Package, containment, shielding, packaging
21.	Closure fasteners	Bolt ring, bolts, screws, threads, clips
22.	Penetrations	Drains, inlets, vents
23.	Vibration resistance (tests, transport environment)	Containment, shielding, compaction of load, physical changes of load

In general, look first at the physical state of the load (solid, liquid, or gas), the package's shape, size, mass, and materials of construction. These items strongly influence the test facilities that are required. Liquids and gasses require a 9 m (30-ft) drop, and packages with large dimensions and masses require test facilities physically capable of handling the packages for the tests that will be conducted. More will be said about test facilities in later sections.

From that starting point move to methods of construction, physical form and dimensions of the load, package type (single or combination), closure, closure fasteners, impact limiters, aspect ratio, penetrations, and dunnage.

Finally, consider the remaining features and their characteristics and anything peculiar to the package design or construction. Remember that the idea is to identify weaknesses that can result in failure when the package is tested.

5.1 WATER SPRAY TEST

> 49 CFR 173.465(b), "Water spray test." *The water spray test must precede each test or test sequence prescribed in this section. The water spray test must simulate exposure to rainfall of approximately 5 centimeters (2 inches) per hour for at least one hour. The time interval between the end of the water spray test and the beginning of the next test must be such that the water has soaked in to the maximum extent without appreciable drying of the exterior of the specimen. In the absence of evidence to the contrary, this interval may be assumed to be two hours if the water spray is applied from four different directions simultaneously. However, no time interval may elapse if the water spray is applied from each of the four directions consecutively.*

In deciding how to apply this test, keep in mind that the test is to serve two purposes. First it is to show that the package can withstand the water spray without suffering damage that results in loss or dispersal of material or an unacceptable increase in radiation levels.

Second, it is to condition the packaging for the other required testing. The condition requirement is aimed at packagings constructed from material that when wetted suffer a reduction in their ability to perform their intended function. For example, a fiberboard box used as the outer packaging may loose enough strength that it tears open during testing. Alternatively, material used to center a load may swell and damage other parts of the package. When looking at the packaging to determine the wait time, don't just look at the visible parts of the package, but consider all the parts that will be wetted. For example, a metal crate may use internal fiberboard spacers. Consider that the package may allow water to enter the outer packaging. If it does, the water must be allowed to soak the parts wetted.

In general, it is recommended the water spray test be physically conducted on at least one packaging of the design type. This recommendation is based on verifying that water will not move into and out of the package in such a manner as to result in a part of the load being carried out of the package. If testing of the design type demonstrates a pass, the data obtained can be used to conduct the required test using one of the other evaluation methods identified in Section 4.0.

Note there is a tendency to want to conduct this test on an empty packaging when it is judged that the water will not result in a reduction of the ability of the packaging to pass the tests. Caution should be used in doing this, as it becomes more difficult to identify loss or dispersal of material. Having a surrogate load present makes that determination easier. If the test is conducted without a load, be sure to prepare documentation identifying that fact and the criteria used to demonstrate compliance.

When applying the water spray, make sure it impinges on the top and sides of the packaging. Try to duplicate rainfall during transportation. Some individuals believe the water runs off the top and down the sides of the package. For some packages this is true. With other designs, it results in no water being applied to the sides although it is running off the top. Consider that the package could be on the back of an open truck moving along the highway, spraying water onto the sides of the packaging.

Caution must be exercised when the other methods for demonstrating compliance are used. For example, when making an evaluation care must be taken to identify all design features and materials that the water will effect. Also, consider the variability in the performance that a design feature may provide. For example, with fiberboard material treated to make it water-resistant, the level of protection is not always even over the entire surface.

When making a comparison to previous testing, care must be taken to assure the features being compared are essentially identical in design, materials of construction, and strength. When a scale model is used, make sure to consider what parameters of the test need scaled to match the model to the full size package. Be sure documentation is available to support the scaling used.

5.1.1 Facility Selection

A water spray facility can be simple. For a small package a garden hose or shower can work. However, remember the water is to be applied as a rain-like spray, not a stream. There are two important items to keep in mind. First, the package should be positioned so that it sits on a relatively flat horizontal surface that drains. The water spray should be applied to hit around the base of the packaging; however, the packaging is not required to sit in a pool or puddle of water. Second, the water spray needs to cover the top surface and sides of the package with a fairly uniform spray. The measurement of the application rate should be made where the spray is least intense. Spraying from all sides at once reduces the test time required, but increases the required flow-rate. For large packaging, the required quantity of water can be considerable if it is used only once. If the water is used only once, adequate drainage is required. If the spray is conducted on an earthen surface, the generation of mud can produce handling problems if the drainage is poor. Remember that for heavy packagings special handling equipment may be required.

5.2 FREE DROP TEST

49 CFR 173.465(c), "Free drop test." *The specimen must drop onto the target so as to suffer maximum damage to the safety features being tested, and:*

(1) The height of the drop measured from the lowest point of the specimen to the upper surface of the target may not be less than the distance specified in Table 12, for the applicable package mass. The target must be as specified in §173.465(c)(5). Table 12 is as follows:

Table 12.—Free Drop Distance for Testing Packages to Normal Conditions of Transport.

Packaging mass	Free drop distance	
Kilograms (pounds)	Meters	(Feet)
<Mass 5000 (11,000)	1.2	(4)
5,000 (11,000) Mass to 10,000 (22,000)	0.9	(3)
10,000 (22,000) Mass to 15,000 (33,000)	0.6	(2)
> 15,000 (33,000) Mass	0.3	(1)

(2) For packages containing fissile material, the free drop test specified in paragraph (c)(1) of this section must be preceded by a free drop from a height of 0.3 meter (1 foot) on each corner, or in the case of cylindrical packages, onto each of the quarters of each rim.

(3) For fiberboard or wood rectangular packages with a mass of 50 kilograms (110 pounds) or less, a separate specimen must be subjected to a free drop onto each corner from a height of 0.3 meter (1 foot).

(4) For cylindrical fiberboard packages with a mass of 100 kilograms (220 pounds) or less, a separate specimen must be subjected to a free drop onto each of the quarters of each rim from a height of 0.3 meter (1 foot).

(5) The target for the free drop test must be a flat, horizontal surface of such mass and rigidity that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase the damage to the specimen.

In deciding how to apply this test, one must look very carefully at the packaging design keeping in mind the following. "The specimen must drop onto the target so as to suffer maximum damage to the safety features being tested…" Note that based on the pass/fail criteria and this requirement, that adequately testing a package using only one drop is very unlikely. For that to occur, the weakness in the package from the standpoint of loss or dispersal of material and changes in radiation level would both need to be tested by the same drop. The following covers some information to keep in mind when determining the orientation and number of drops to conduct.

Type A packagings, unlike POP, have no shape, volume, or weight limitations. Therefore, prescribing drop orientations to be used for all packagings is not possible. For those packages that match the materials of construction, size, and shape range of a POP, the tests prescribed for that type of POP package are a good starting point. Note that while multiple drops are not specifically identified for radioactive materials, they are required for POP. Remember also that radioactive material packaging regulatory compliance is based on no loss or dispersal of material and no significant increase in the radiation level. Because of the differences in pass/fail criteria, a package that passes POP testing can fail as a radioactive material package.

When determining the orientations and number of free drop tests to conduct, keep in mind both the external and internal forces that occur during impact. Contact of the external features of the packaging with the target is just the beginning. All of the inner packagings and the load are being stopped, and their energy and movement must be considered. Remember to look for packaging orientations where damage to the closure from internal packagings and load may fail the package. Also, watch for internal changes or damage that are more significant from the standpoint of changes in radiation level. Keep in mind that while solids tend to apply their force in the direction of the drop, that granular solids, liquids, and gases result in the force being distributed in other directions as well. A look at the static loading can provide some insight into where the forces are likely to distribute during impact.

5.2.1 Facility Selection

The first five package features listed below have a strong influence on the selection of a test facility and the equipment needed to conduct the tests. When looking at the package to determine how to test, consider the equipment that is needed to conduct the drop test and the available facilities.

5.2.1.1 Shape. Shape slightly influences the selection of a free drop test facility in that the facility must be capable of handling the packaging. It also has some influence on the selection of the target. Some shapes result in a more concentrated impact load than others.

Shape strongly influences orientation of the package for testing. This results from the influence of the shape on both construction of the packaging and on the distribution of forces that result from the impact.

In general, spherical packagings have fewer features requiring orientation considerations. This results from symmetry in the design and construction features. Weakness will be generally located at the penetrations and supports. Packages of this shape are usually used for liquids or gases. Drops onto the penetrations of the packaging are recommended.

Another easy package shape to deal with is the cube. Radioactive material packages ranging from a 10 cm (4 in.) cube up to a 3.7 m (12 ft) cube have been observed. Packages of this shape are usually use for transporting solids. The cube-shaped package is nice from the standpoint of selecting and rigging an impact orientation. If the package is uniformly constructed and loaded, picking it up from the diagonally opposite corner results in the proper angle for a center of gravity over the impact point corner drop. For edge drops, the diagonally opposite edge is a good pick point. Normal loading often results in an off-center load. This requires adjusting the angle to compensate for shifts in the load. In general for single-walled packagings, a center of gravity over the corner impact results in a rigorous test of the packaging's containment. However, the choice of corner is not necessarily easy. Variations in design between the closure area, the sides, top and bottom can make choosing an orientation difficult. If the designer has not provided an evaluation of the ability of the box to withstand impacts in various orientations and if the design does not show a significant weakness, then several drop orientations are in order.

Cylinders, with a height that matches the diameter, are another shape where a test orientation is easy to select. The ends may be flat or have a radius. Cylindrical-shaped packages are used for shipping solids, liquids, and gases. This shape of package generally has an axis about which it is symmetric. Weaknesses are likely to be at closures, supports, and for tank-type packagings at the penetrations.

Rectangular packagings where the long dimension does not exceed twice the length of the next longer of the other two dimensions are similar to a cube in determining the drop orientations to use. Note that with this shape of package that the initial impact may not be the most energetic. Consider that with a uniform load it is possible for the center of gravity at impact to still be higher above the target than the impact point was at the start of the drop. With a non-uniform load, the center can be higher yet. With rectangular packagings, watch for features to subject to the secondary impact. Rigging for corner drops is more difficult for rectangular-shaped packages than for cubic shapes. Multiple attachment points and/or adjustable slings make obtaining the proper angel easier.

Rectangular or cylindrical packaging where the length is greater than twice the diagonal of the small side or diameter will in general have the drop angle driven more by the contents than the shape of the package. The load in these packages is often a single long object, or for cylindrical packages a gas or liquid. For a liquid or fluid solid material, consider a flat on the end drop. For a long solid object, look at dropping on the shortest edge. As with rectangular packagings, watch for features to subject to the secondary impact. Penetrations and supports are two common secondary targets.

The term "multifaceted" in Table 5-1 is meant to cover all other shapes. Because the package can have any shape with many sides, no real guidance based on shape can be given. In deciding how to drop these packagings, look for features that generate weakness that if subjected to impact can result in packaging failure. Remember also to look at maximizing the forces from the load on available weakness.

5.2.1.2 Physical Dimensions. The physical dimensions of the package influence testing primarily in two ways. When discussing shape, it was pointed out that when the length became large in comparison to the other dimensions, that the primary impact was not always as serious as the secondary impact.

The more important aspect of the packaging dimensions is their delineation and influence on the equipment used by the test facility. To pick an extreme, consider the need to conduct a 9 m (30 ft) drop test on a 9 m (30 ft) long package. Depending on how the package was rigged it would require at a minimum a facility with a clearance above the test pad of over 18 m (60 ft). Continuing with this same packaging it would require a target whose surface dimensions are large enough to ensure the secondary impact is also onto the target. As there is no way to guide the free drop or account for bounce, the dimensions of the target would be quite large. While a Type A, 9 m (30 ft) long liquid package is not likely; a 9 m (30 ft) long package for solids is. The surface dimensions needed are not much different in either instance.

5.2.1.3 Mass of Package. The mass of the package does not directly effect how the package is oriented for the test. The location of the center of mass does. Note that in most instances locating the center of gravity over the impact maximizes the damage in the area of impact.

The mass strongly influences the required test facilities. First a facility must be capable of supporting the packages that are supplied for testing. Equipment is needed for moving the packages to and from the test site. Equipment is needed to lift the package to the required drop height. To meet the recommendations of the IAEA for testing radioactive materials packaging, the target requires a mass of ten times the mass of the packaging to be dropped. The mass also influences the materials of construction used for the target. The target must be unyielding in comparison to the package. This requires the target materials to be capable of withstanding the concentrated forces that result at impact.

5.2.1.4 Materials of Construction. The materials used to construct the package do not directly effect how the package is oriented for testing. When looked at in conjunction with the shape of the package, materials of construction can influence the test orientation decisions. For example, the strength of wood varies with the angle of the force to the direction of the grain. In packages made from wood, this might make one impact point weaker than another that is similarly shaped. Other materials have similar properties that should be kept in mind when determining how to test the packaging.

The materials do effect the selection of the target used for the drop test. It is required that the target be unyielding. To meet this requirement, the target should be built from a material that has a greater impact resistance than the packaging. While a concrete target surface may work well for a package of fiberboard or softwood, it may not be suitable for steel. When possible, select a target with a high-grade steel (armor plate) surface. In all cases watch that the target does not suffer significant damage. For example, consider that a large chip out of a concrete surface when testing a drum-type package may indicate that significant energy went into removing the chip rather than into damaging the package.

5.2.1.5 Physical State of the Load. The physical state of the load has a very direct effect on the required testing facilities. Note that both gases and liquids require that the package be dropped 9 m (30 ft). The higher free drop height requires a higher clear area above the target. It also requires lifting equipment capable of lifting the package into position. In addition, the target must resist a larger force due to the additional drop height.

The physical state of the load can effect the package orientation during testing. Packages containing liquids and fluid solids can have a shift in the location of the center of gravity when they are placed in the drop orientation. When calculating the exact package orientation, keep in mind the shifting materials and compensate.

When choosing the impact point keep in mind that liquids and fluid solids result in increases in loading on the sidewall with depth. During impacts, the forces for these types of materials will distribute differently than if loaded with a solid material. This can result in localized forces that are high above the average forces on the walls.

Another factor making the choice of drop orientation difficult is the requirement that there be no significant increase in radiation levels. If the radioactive material does not fill the package, and is not essentially uniformly distributed throughout an essentially uniformly dense load, shifting during testing can result in failure. Materials that can be significantly compacted by testing may also result in changes in radiation levels. When point sources are held inside a packaging, consider both movement of the load within the packaging and bending of the package walls. With point sources, small changes in distance result in large increases in radiation levels.

With solids, watch how the inner surfaces of the package are loaded. For example, a package having external skids/runners, containing a smooth-based concrete block, is uniformly loaded. The same package loaded with the same weight, containing a concrete block supported by skids/runners that are parallel to the package's external runners, and placed on the box bottom mid-way between the runners, has a much different load. Poorly executed blocking and bracing placed around the load can have a similar effect during testing.

5.2.1.6 Methods of Construction. When determining how to conduct the drop tests look for weakness in how the packaging is constructed. When tape and/or glue is used look to see if there is an orientation that can result in impact forces that will overcome the adherence forces. With tape, look for a way that it can fail by tearing. Nails, rivets, staples, and screws usually provide enough resistance in shear. Are they installed such that an orientation can be identified that results in them pulling out? For formed, extruded, and cast materials, do they have areas where they are weak due to thinning or contain residue stress? With welding, look at the quality of workmanship. Is the welding continuous inside and outside of the package? Is the weld continuous, skip or spot? Does the weld look adequate for the application when subjected to testing? For example, short skip welds on a runner may be fine for normal use, but during drop testing these type of welds can result in concentrated forces that tear a hole through the packaging walls.

Look closely at the design of the joints. Butt joining is a possible weak feature. Lapped joints are stronger. How are the joints held together? Are the joints sealed, if so how? Are the joints located in high stress areas or low stress areas? If an edge joint looks weak, try a center of gravity over the edge drop.

Many people believe that the closure is the weakest part of the package. This is not always the case. Closure designs often result in more time being spent on this particular feature and generally add additional material. Often the sides and bottom are significantly weaker from a structural standpoint. This is especially true for an impact load such as occurs during testing. Look closely at the design of the joints. Butt joining of side-to-side and side-to-bottom are a possible weak feature. If an edge joint looks weak, try a center of gravity over the edge drop. For large boxes with runners, look at the bottom. Is an impact on a runner likely to damage the box? During testing, tack welds used to secure runners have resulted in tearing of holes in the bottom of the package. In addition, removable runners have fallen off during the initial impact. The packaging has then fallen onto the runner, puncturing the package.

When looking at the joining of materials, look at the joining inside and out. Full welds on both sides are more likely to pass than a single weld. Over-lapped joints are usually stronger than butt joints. Joints positioned away from corners and edges will generally see less stress. Watch for spot or short skip welds, or similar fastening techniques as they can result in stress concentrations during testing that result in tearing the material.

Other features to watch for are protrusions above the general surface. During drop testing, a protrusion can be pushed through the wall or can serve as a starting point for a tear. Note that during drops the damage does not stop with the initial impact. The package may bounce or rotate around the impact point and strike the target with another impact. Skidding can occur. The skidding can result in large side forces being applied to surface protrusions.

Consider penetrations as they can result in weakness in the containment. This can result from a reduction in strength of material in the area, a thinning of shielding, or from the closures used on the penetration.

5.2.2 Number of Test Specimens

The regulations permit the use of a new packaging for each test or the same package for all tests. In both situations, the package must meet the water spray conditions. The test facility can make recommendations based on experience. A packaging subjected to more than the required number of tests can fail due to previous damage that is not visible. If the package fails during the second test, evaluating and explaining the reason for the failure could be more costly than the cost of an additional test specimen. If it is clear that the design will withstand the complete series of tests, go with one test unit. If there is any question, increase the number of recommended test specimens and select the tests conducted on a specimen to avoid failure due to hidden damage or from applying repetitive forces to the same features. The choice of how many test units to use should be made by the test sponsor (customer).

Several other factors influence the decision on the number of packagings to test. Packagings that are going to be used extensively should be thoroughly tested. Multiple drops in the same orientation should be considered. A packaging whose design appears marginal should receive additional testing. Consider the variability in strength permitted by the design. The packaging tested should represent the weakest packaging likely to be produced. Packagings, that during testing appear to just pass, should have additional tests conducted.

5.2.3 Other Evaluation Methods

Using methods other than testing for evaluating the ability of a packaging to pass drop-testing requirements requires extreme care. For example, how is the magnitude of impact loadings determined and where should the loadings be applied when evaluating a drop. As with actual testing the evaluation of more than one impact orientation may be required. Determining what secondary impacts to evaluate is often overlooked. For some packagings, for example long skinny ones, the secondary impact may be more critical than the initial impact. Choosing the orientation for the secondary impact should be based on what happens at the initial impact. Based on that reaction, the weakest feature to be challenged by the secondary impact should be identified. For example, with a box dropped onto the bottom corner, rotation about the point of impact and striking on the runners might stress the weakest feature. If the box has a valve, perhaps rotation about the point of impact such that the valve is subjected to the secondary impact would be a worse scenario. Remember, when making the determination, you are looking to identify the drop that will result in maximum damage to the feature being evaluated. Remember the secondary impact is to be realistic. Don't evaluate what cannot happen.

When making comparisons remember to watch the small details. While a corner joint may look similar, small differences in the length of a member or weld can cause a significant shift on where the energy is expended.

5.3 STACKING TEST

> 49 CFR 173.465(d), "Stacking test." *(1) The specimen must be subjected for a period of at least 24 hours to a compressive load equivalent to the greater of the following:*
>
> *(i) Five times the mass of the actual package; or*
>
> *(ii) The equivalent of 13 kilopascals (1.9 pounds per square inch) multiplied by the vertically projected area of the package.*
>
> *(2) The compressive load must be applied uniformly to two opposite sides of the specimen, one of which must be the base on which the package would normally rest.*

In applying this test there are few variables to consider. The determination of which load is greater was already discussed. The designer selected the packaging orientation. The remaining questions to address are what compression method should be used and what surface should the package be placed on to obtain the bottom loading. The usual compression methods used are the application of dead weights or the use of a compression test machine.

When the method of loading the packaging with dead weight is selected, the choice of the surface on which to place the package must be made. The drop test target, if available, makes a good surface. If it is not available, look for a surface that will resist the forces it will see from the total weight. Note that a packaging with runners will concentrate the force to a smaller surface area. During testing, packagings have been observed to sink into the asphalt pad on which they were placed. If the package sinks too deep, it may transfer load to the bottom of the packaging. If it does not settle evenly, it can result in a shifting of the dead weights. Shifting of the weights can produce a safety problem and possibly an improper test loading. Use caution when conducting the load test. Remember that if the packaging fails, the load is likely to topple. The test site should supply a clear area around the packaging to allow for failure. In general, with this method, the force on the packaging remains constant over the test period as required.

The loading of the top surface of the package with many small weights verses one large weight that covers the packaging needs to be considered. Note that a single rigid weight may load the outside edges and walls of the package but not the top surface material. If the top surface does not appear adequate to carry the weight applied by a series of small weights, then it should be tested with that type of load.

When loading with a compression test machine the choice of surface on which to place the package is not an issue. There are two things to consider with this type of test. One is to make sure that the machine will retain the full compression force over the test period. Note that some machines will relieve the applied force if there is yielding in the packaging that results in movement of the platen used to apply the force. The next consideration is distribution of force that is applied to the top surface of the packaging. As discussed above, if the top surface does not appear adequate to carry the weight applied by a series of small weights, then it should be tested with that type of load.

At the conclusion of the stacking test, check the package for changes that result in the loss or dispersal of material and/or result in increases in the surface radiation levels. Be sure to examine joints and edges for failure. If the package sits on supports or runners examine the surfaces around them for signs of failure.

5.3.1 Facility Selection

A stacking test facility can be simple. For small lightweight packages most floors, workbenches, tables or an earthen surface will make an acceptable surface on which to rest the package. The load can be just about anything that will rest on top of the package such that the top is uniformly loaded. Packages with tops that are not horizontal take some planing, and at times, some rigging to hold the load in position. For heavy packages or packages equipped with feet or runners, make sure that the surface will support the concentrated weight of the package and the required load. When a compression machine is used, make sure it holds the package and supplies the required compressive force. If there is any chance that the package will yield over the required test period, make sure the machine is designed to apply a continuous force of equal magnitude. With some machines, the force will be reduced if the package yields and allows the platen to move. Look for a facility that is equipped to handle packagings of the shape, size, and mass to be tested.

5.3.2 Evaluation of Stacking

Evaluations of stacking by calculations or comparisons are fairly straightforward. Remember though to look carefully at where the forces from the load are carried. Small seemingly insignificant differences in design can make a big difference in where the load is carried. For example if a corner stiffener does not run from a bottom support all the way to the top, a panel rather than the frame may carry the weight. Runners that do extend the full width of the bottom can result in moments about the end of the runner. As with an actual test, a pretest determination of the package is needed. Review the design looking at the tolerances. Evaluate the feature under the conditions that the design permits that will result in maximum damage. For example look at the smallest weld permitted, not the best or typical.

5.4 PENETRATION TEST

> 49 CFR 173.465(e), "Penetration test." *For the penetration test, the specimen must be placed on a rigid, flat, horizontal surface that will not move significantly while the test is being performed.*
>
> *(1) A bar of 3.2 centimeters (1.25 inches) in diameter with a hemispherical end and a mass of 6 kilograms (13.2 pounds) must be dropped and directed to fall with its longitudinal axis vertical, onto the center of the weakest part of the specimen, so that, if it penetrates far enough, it will hit the containment system. The bar may not be significantly deformed by the test; and*
>
> *(2) The height of the drop of the bar measured from its lower end to the intended point of impact on the upper surface of the specimen must be 1 meter (3.3 feet) or greater.*

In applying this test, the main emphasis is on the packaging containment. The test is intended to assure that the package is not likely to fail if subjected to a puncture type incident during shipment. The package should be inspected to determine what is the weakest containment feature for resisting puncture. This includes weak features on the sides and bottom of the packaging. The packaging should then be orientated to place that feature upward and as horizontal as possible. The package must be on a surface that prevents motion of the packaging during the test. The penetration bar is dropped onto the impact point. If the bar does not strike as desired, the test should be repeated. Some organizations use a guide tube for the penetration bar. If a guide tube is used, care must be taken to assure that the tube is vertical, does not restrict the free fall of the bar, and does not interfere with the determination of the drop height. Although the emphasis is on containment, watch for a weakness that could result in failure of shielding. If a weakness exists, test it also. The penetration bar should be inspected before and after the test for deformation. If significant deformation of the bar is identified prior to testing, replace the bar. If significant deformation of the bar is identified after testing, replace the bar and repeat the test. After testing, the bar should show no significant deformation.

5.4.1 Facility Selection

A penetration test facility can be simple. For small lightweight packages most floors or the ground will make an acceptable surface on which to rest the package. The package surface being tested needs to be aligned perpendicular to the vertically dropped bar. This may require material or jigs to hold the package in the right orientation during the test. The package must be held firm enough that it does not move when impacted by the bar. Heavy packages require a surface adequate to support them. The bar should be made from a material that will not be deformed by the impact onto the package. The facility should provide enough room that the work can be conducted safely. Note that if a guide tube is not used, the bar may rebound and fall in any direction. Make sure that personnel and equipment that can be damaged are kept out of the way.

Look for a facility that is equipped to handle packagings of the shape, size, and mass to be tested.

5.4.2 Evaluations of Penetration

Evaluations by comparisons and calculations are usually straightforward. The same care that is applied when determining where the impact bar should impact should be applied to the evaluations. Make sure to evaluate the weakest part of the packaging's safety feature.

5.5 ADDITIONAL TESTS

> 49 CFR 173.466, "Additional tests for Type A packagings designed for liquids and gases."
>
> *(a) In addition to the tests prescribed in §173.465, Type A packagings designed for liquids and gases must be capable of withstanding the following tests:*
>
> *(1) Free drop test. The packaging specimen must drop onto the target so as to suffer the maximum damage to its containment. The height of the drop measured from the lowest part of the packaging specimen to the upper surface of the target must be 9 meters (30 feet) or greater. The target must be as specified in §173.465(c)(5).*
>
> *(2) Penetration test. The specimen must be subjected to the test specified in §173.465(e) except that the height of the drop must be 1.7 meters (5.5 feet).*

Note that these two tests are in addition to, not in place of, the drop and penetration tests identified in 49 CFR 173.465. In addition, for the drop orientation the emphasis is on testing the containment. The discussions above on the selection of packaging orientation are also applicable to these tests.

When determining the drop test orientation it may be helpful to have completed the 1.2 m (4-ft) drops first. The data obtained from the lower drop height will provide information on the weak features of the packaging, and the rigging of the packaging. Note that during the 9 m (30-ft) drop, the initial drop angle becomes more important as the package will have longer to rotate during the drop. If too much rotation occurs, the test may require repeating.

6.0 VERIFICATION OF DESIGN REQUIREMENTS BY TESTING

There are two design requirements that are often verified by testing the packaging. They are the ability to withstand acceleration and vibration, and the ability to withstand a reduction in atmospheric pressure. The first of the requirements is found in 49 CFR 173.410(f) and is applicable to all radioactive material packagings covered by this document. The second requirement is found in 49 CFR 173.412(f), it is applicable to IP-3 and Type A packages.

6.1 ACCELERATION AND VIBRATION

49 CFR 173.410, "General design requirements."

(f) The package will be capable of withstanding the effects of any acceleration, vibration or vibration resonance that may arise under normal conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole and without loosening or unintentionally releasing the nuts, bolts, or other securing devices even after repeated use (see §§ 173.24, 173.24a, and 173.24b).

The above requirements, including the referenced sections, do not require physical testing of the packaging. Section 173.24a(a)(5) *vibration* sets a requirement for non-bulk packages to be able to pass a vibration test identified in 49 CFR 178.608, "Vibration standard." To demonstrate the ability to meet the vibration requirements, non-bulk radioactive material packagings are often subjected to the vibration test identified in 49 CFR 178.608. Larger radioactive material packagings are sometimes subjected to the vibration test requirements identified for intermediate bulk packagings in 49 CFR 178.819, "Vibration test." In both cases the number of packages subjected to the test and method of determining no loss or dispersal of material are varied to match the packaging's use as a radioactive material package.

When determining if or how to conduct a vibration test keep in mind that the intent is to show that the package will retain the radioactive load with no loss or dispersal of material and no significant increase in radiation levels. If a decision is made to test, it is recommended that, when possible, the test be conducted on the number of test units identified in the test description applicable to the size package to be tested. If the variability in construction is wide, try to select packages that represent the extremes as well as the average package. If a large number of packages are to be constructed, consider increasing the number of packages tested.

After testing, look not only for loss or dispersal of material, but for signs that the radiation level on the surface of the package is significantly effected. Keep in mind movement of the load and or shielding, changes in distance between the load and the package surface, loss of shielding, and concentration of the load.

6.1.1 Evaluation Methods

If a decision is made not to test, then document an evaluation of the package's ability to pass the vibration and acceleration requirements. When making the evaluation, keep in mind the above items to look for after testing. The evaluation should make it clear that the package will survive transportation without loss or dispersal of material or a significant increase in radiation level on the surface of the package. The evaluation can use any of the methods identified. With pure evaluations be sure to consider the effects not only on the closure, but also on the package as a whole, and on the ability of the package to maintain shielding. For comparisons, make sure the package is similar. For example, don't compare a drum having a point source to one having a distributed load.

6.2 REDUCED PRESSURE

> 49 CFR 173.412, "Additional design requirements for Type A packages."
> *(f) The containment system will retain its radioactive contents under the reduction of ambient pressure to 25kPa (3.6 pounds per square inch).*

This requirement is often demonstrated by conducting a pressure test on the package. Assuming the package is packed at the standard pressure, a reduction in the ambient pressure results in a differential pressure (inside to out) of 76 kPa (11.1 lb/in.^{2}). Unless the package has a reduced atmosphere, this represents the smallest pressure difference the package should be designed to withstand. In most cases, the package is likely to see a larger differential pressure due to the production of gas within the containment boundary. For a liquid or gas package, the additional pressure from the load needs to be added to the minimum pressure.

Various methods for conducting pressure tests are available. Keep in mind that some test methods result in the storage of more energy in the package than others methods do. When the material to be shipped and the packaging design allow, it is recommended that an uncompressible hydraulic fluid be used to pressurize the containment vessel. This will result in the least amount of stored energy inside the package. Another way of reducing the stored energy is to fill the chamber with an uncompressible hydraulic fluid or solid and apply the pressure with a small volume of gas. If a compressed gas is used, some form of personal protection should be provided. Small packagings can be prepared as for shipment and placed into a vacuum chamber. Keep in mind that if the package contains a large amount of gas, that this is similar to adding compressed gas to the package. Depending on the chamber and the design of the packaging, additional blast shielding may be necessary.

For packagings that do not have an opening through which pressure can be applied, it may be necessary to add a feature. If this is done, use caution not to reduce the strength of the packaging to the point where failure results, or to change the packaging in such a way as to invalidate the test.

6.2.1 Evaluation Methods

For packagings that are not sealed an evaluation should be made of the ability of the package to withstand the reduction in pressure. Note that the regulations do not discuss the rate of change of the pressure. For packages shipped by surface mode of transportation, the change will most likely take a significant amount of time, say tens of minutes. The fastest change that would take place during surface travel is with a truck traveling through the mountains. For surface travel, the package is only likely to see differential of the test magnitude if an unanticipated gas generation event occurs in the package. For air transportation, the change will occur in a few minutes as the plane climbs to cruising altitude. These factors should be considered during the evaluation.

7.0 REFERENCES

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