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DESIGN CONSIDERATIONS PRIMER FOR CARGO CONTAINERS

Main Category:	Mechanical Engineering
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OFFICIAL COURSE/EXAM

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MEC-142 EXAM PREVIEW

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Exam Preview:

1. According to the reference material, for the purposes of this document, the word "should" is used to denote a requirement which is supported by a standard or regulation.
    a. True
    b. False
2. Using The Regulations for the Safe Transport of Radioactive Materials routine conditions of transport, which of the following acceleration factors corresponds to Sea Lateral loadings?
    a. 1g
    b. 2g
    c. 3g
    d. 5g
3. Which of the following third-party approval agencies is responsible for producing the following rules of certification: Rules for the Classification and Certification of Freight Containers?
    a. Germanischer Lloyd
    b. Lloyds Register
    c. Bureau of Veritas
    d. DET Norske Veritas
4. According to the reference material, the quality control manual should include all of the following elements: Description of Organization, Materials Identification, Workmanship Quality, Control Records, and Fabrication QC Methods.
    a. True
    b. False

5. According to the Design Considerations section of the reference material, a roof load simulates two ___ lbs. workers on roof for a total load of ___ lbs.
    a. 150, 300
    b. 220, 440
    c. 250, 500
    d. 185, 370
6. According to the reference material, 40-ft freight containers may not have forklift pockets.
    a. True
    b. False
7. According to the Design Considerations section of the reference material, to ensure front and end panels can withstand cargo load forces resulting from rail coupling impacts or highway breaking a load of ____P uniformly distributed outward over the front and rear end panels.
    a. 0.6
    b. 0.7
    c. 0.4
    d. 0.5
8. According to the reference material, if inspection personnel deem quality control procedures adequate, the pull test may be performed on one container from each lot of twenty-five (25) containers.
    a. True
    b. False
9. When testing in accordance with ISO -1496-1, when lifting from bottom corners, lifting forces shall be applied at 45° to horizontal for a 20' container. The container shall be suspended for __ min.
    a. 5
    b. 10
    c. 15
    d. 25
10. When testing in accordance with ISO -1496-1, when testing for weather proofness, A stream of water shall be applied on all exterior joints and seams of the container. The nozzle shall be held at a distance of 5 feet from the container and be moved at a speed of __ inches per second.
    a. 2
    b. 3
    c. 4
    d. 5

Foreword

The following is a primer on the design considerations for cargo freight containers. The document is meant to serve as an introduction to cargo fright design. Please refer to the referenced standards for full design specifications.

Historical Background

During the 1960s, the rapid increase in the use of freight containers for the consignment of goods by sea and the development of specialized container ships caused the International Maritime Organization (IMO) to undertake a study of the safety of containerization in marine transport in 1967. The container itself emerged as the most important aspect to be considered. In 1972, a conference was held to consider a draft convention prepared by the IMO in cooperation with the Economic Commission for Europe. The conference was jointly convened by the United Nations and the IMO. The 1972 Convention for Safe Containers had two goals. One was to maintain a high level of safety of human life in the transport and handling of containers by providing generally acceptable test procedures and related strength requirements that would prove adequate over years of use. The other was to facilitate the international transport of containers by providing uniform international safety regulations, equally applicable to all modes of surface transport. In this way, proliferation of divergent national safety regulations could be avoided.

The requirements of the Convention apply to the great majority of freight containers used internationally, except those designed specifically for carriage by air. As it was not intended that all containers, vans, or reusable packing boxes should be affected, the scope of the Convention was limited to containers of a prescribed minimum size having corner fittings—devices that permit handling, securing, or stacking. The Convention established procedures whereby containers used in international transport will be safety approved by an administration of a contracting state or by the organization acting on its behalf. The administration or its authorized representative will authorize the manufacturer to affix a safety approval plate containing the relevant technical data to approved containers. The approval, evidenced by the safety approval plate granted by one contracting state, should be recognized by other contracting states. This principle of reciprocal acceptance of safety-approved containers is the cornerstone of the Convention; and once approved and plated, it is expected that containers will move in international transport with the minimum of safety control formalities.

The United States accepted the Convention requirements and adopted them on January 3, 1978. The United States designated the U.S. Coast Guard as the responsible organization to ensure compliance with the International Convention for Safe Containers (CSC) (See A). This was adopted by law and incorporated into 49 CFR Parts 450–453. The U.S. Coast Guard may elect to authorize other organizations to ensure compliance with the International Convention for Safe Containers (CSC) requirements, e.g., American Bureau of Shipping (ABS).

Definitions

Approved Test A proposed test plan submitted to the Third Party Approval Agency with the application for a new design as to how each of the tests in ISO 1496-1 will be conducted. When approved by the Third Party Approval Agency, their surveyor when witnessing the ISO 1496-1 tests, ensure these tests are performed as planned.

Carrier (49 CFR 171.8): A person who transports passengers or property in commerce by railcar, aircraft, motor vehicle, or vessel.

Closure: Those mating parts of a packaging system designed to be opened and closed and all associated devices needed to hold those components securely closed during transport, including any gaskets or sealants designed to prevent loss or dispersal of the contents.

Competent authority (49 CFR 171.8): A national agency responsible under national law for the control or regulation of a particular aspect of the transportation of hazardous materials (dangerous goods). The term "appropriate authority," as used in the International Civil Aviation Organization (ICAO) Technical Instructions (incorporated by reference; see 49 CFR 171.7), has the same meaning as "competent authority." For purposes of the hazardous materials regulations, the Associate Administrator for Hazardous Materials Safety of the DOT Pipeline and Hazardous Materials Safety Administration (PHMSA) is the competent authority for the United States.

Consignee: Any person, organization, or government that receives a consignment.

Container Test Report: A document that records the actual tests and their results of each test performed as required in the approved test plan.

Containment system (49 CFR 173.403): The assembly of components of the packaging (when assembled) intended to retain the Class 7 (radioactive) contents during transport.

Design (ANSI N14.7): A description of the packaging that may include specifications, engineering drawings, reports showing compliance with regulatory requirements, gross weight, materials of construction, materials used as shielding, external dimensions and cavity size, internal and external structures, valves, sampling ports, means of heat dissipation, lifting and tie-down devices, amount of shielding, closures, and means of containment. The containment and shielding components should be clearly identified. Overall and cutaway sketches of the package should be included as part of the design description, as well as drawings that clearly detail the safety features considered in the analysis, including material lists, dimensions, valves, and fasteners. Drawings should specify the requirements for all packaging weld joints; joints for gaskets should be sufficiently detailed to show the surface finish and flatness requirements of the closure surfaces; the gasket specification; and, if appropriate, the method of gasket retention.

Designer (ANSI 14.7): The person or organization that develops the design by selecting the assembly of components and materials to be used for the packaging of particular radioactive material contents. The designer should have a working knowledge of the proposed radioactive contents, packaging engineering concepts, DOT Type A design and performance requirements, and use or functionality of the packaging.

The designer applies this knowledge to determine the components of the packaging; ensures that the design demonstrates the capability to fulfill all design requirements; and specifies the criteria for which the packaging is to be fabricated, tested, and closed. In some instances the designer may also be the fabricator and/or the shipper/offeror.

Dispersible radioactive material: For the purpose of this document, dispersible materials are radioactive materials that could become released or leaked from the packaging due to conditions normal to transport (i.e., vibrations, accelerations, temperature, pressure). Examples of dispersible contents include unpackaged low level waste, piping or components with exterior contamination, or oxide contents, fines, powders in containers that cannot be shown to withstand routine vibrations or accelerations (e.g., badly deteriorated drums or boxes).

Engineering analysis (ANSI N14.7): Engineering analysis of a package design involves separating the design into components to demonstrate that containment, shielding, and thermal performance of the overall package are maintained under the testing and performance conditions specified in the regulations. Analysis methods include comparison, hand or computer calculations, and reasoned analysis.

Fabricator (ANSI N14.7): The person or organization that fabricates or assembles the packaging components of a specific design, as specified by a customer. In some instances the fabricator may also be the designer and/or the shipper/offeror.

Freight container (IAEA Safety Standards TS-R-1, 2005-223): An article of transport equipment that is designed to facilitate the transport of goods, either packaged or unpackaged, by one or more modes of transport without intermediate reloading which is of a permanent enclosed character, rigid and strong enough for repeated use, and must be fitted with devices facilitating its handling, particularly in transfer between conveyances and from one mode of transport to another. A small freight container is that which has either any overall outer dimension less than 1.5 m, or an internal volume of not more than 3 m3. Any other freight container is considered to be a large freight container.

Freight container (49 CFR 173.403): A reusable container having a volume of 1.81 cubic meters (64 cubic feet) or more, designed and constructed to permit it being lifted with its contents intact and intended primarily for containment of packages in unit form during transportation. A small freight container' is one, which has either one outer dimension less than 1.5 m (4.9 feet) or an internal volume of not more than 3.0 cubic meters (106 cubic feet). All other freight containers are designated as large freight containers.

Freight container (also see “Standard Freight Container” below)

Freight container modifications affecting original certification: Modifications that affect the previous approved design of the container by the competent authority (e.g., U.S. Coast Guard) or their designee (e.g., American Bureau of Shipping). In most cases, any modification that affects the structural integrity of the container and for which the competent authority can require new testing to be performed.

Freight Container Modifications that do not affect its original certification: Modifications that do not affect the certification of the container by the competent authority or their designee. In most cases, these are modifications that affect the structural integrity of the container.

Inner Containment: An inner receptacle or container that acts as a containment boundary of the contents, but is not capable of meeting all the requirements of the regulations. The inner containment must be placed in an outer packaging to meet all transportation requirements.

Low Specific Activity (LSA) material (49 CFR 173.403): Class 7 (radioactive) material with limited specific activity which satisfies the descriptions and limits set forth below. Shielding material surrounding the LSA material may not be considered in determining the estimated average specific activity of the package contents. LSA material must be in one of three groups LSA-1, LSA-2, or LSA-3.

Modified Freight Container: Containers that have been modified from their original design. The modifications that have been made may or may not violate the original certification of the container.

Non-Dispersible radioactive material: Contents consisting of solid radioactive materials of a sufficiently large (particle) size so as not to leak from the freight container. Non-dispersible contents include solid activated materials that will not break down or disintegrate into fines during transport, flanged hardware components with internal contamination, piping with wrapped ends with internal contamination, or bagged homogeneous/non-puncturing waste. Non-dispersible radioactive materials should either be of a form that is 1) robust enough to remain as a solid unit without disintegration; or 2) be confined in inner packaging (bagging, drums, and boxes) that can be shown to withstand routine conditions of transport.

Non-fixed radioactive contamination: Radioactive contamination that can be readily removed from a surface by wiping with an absorbent material. Non-fixed (removable) radioactive contamination is not significant if it does not exceed the limits specified in 49 CFR 173.443.

Normal conditions of transport (ANSI N14.7): A term used in both the DOT and IAEA regulations to encompass rough handling and minor mishaps during transportation. Type A packages are required to demonstrate that they can withstand normal conditions of transport by meeting the performance and containment requirements of 49 CFR 173.412, 465, and 466.

Off-the-shelf freight container: Containers that available for sale or lease, comply with their original design, and have not been modified.

Package (49 CFR 173.403): The packaging together with its radioactive contents as presented for transport.

(1) **Excepted package** means a packaging together with its excepted Class 7 (radioactive) materials as specified in Sec. Section 173.421-173.426 and 173.428.

(2) **Industrial package** means a packaging that, together with its low specific activity (LSA) material or surface contaminated object (SCO) contents, meets the requirements of Sections 173.410 and 173.411. Industrial packages are categorized in Section 173.411 as either:

(i) "Industrial package Type 1 (IP-1)";

(ii) "Industrial package Type 2 (IP-2)"; or

(iii) “Industrial package Type 3 (IP-3)”.

Packaging (49 CFR 173.403): For radioactive material, the assembly of components necessary to ensure compliance with the packaging requirements in 49 CFR 173, Subpart I. It may consist of one or more receptacles; absorbent materials; spacing structures; thermal insulation; radiation shielding; service equipment for filling, emptying, venting, and pressure relief; and devices for cooling or absorbing mechanical shocks. The conveyance, tie-down system, and auxiliary equipment may sometimes be designated as part of the packaging.

Person (49 CFR 107.1 and 171.8): An individual, firm, co-partnership, corporation, company, association, or joint-stock association (including any trustee, receiver, assignee, or similar representative) or a government or Indian tribe (or an agency or instrumentality of any government or Indian tribe) that transports a hazardous material to further a commercial enterprise or offers a hazardous material for transportation in commerce. Person does not include the following.

(1) The US Postal Service.
(2) Any agency or instrumentality of the federal government, for the purposes of 49 U.S.C. 5123 (civil penalties) and 5124 (criminal penalties).
(3) Any government or Indian tribe (or an agency or instrumentality of any government or Indian tribe) that transports hazardous material for a governmental purpose.

Person who offers or offeror (49 CFR 171.8):

(1) Any person who does either or both of the following:

(i) Performs, or is responsible for performing, any pre-transportation function required under this subchapter for transportation of the hazardous material in commerce.

(ii) Tenders or makes the hazardous material available to a carrier for transportation in commerce.

(2) A carrier is not an offeror when it performs a function required by this subchapter as a condition of acceptance of a hazardous material for transportation in commerce (*e.g.*, reviewing shipping papers, examining packages to ensure that they are in conformance with this subchapter, or preparing shipping documentation for its own use) or when it transfers a hazardous material to another carrier for continued transportation in commerce without performing a pre-transportation function.

Pre-transportation function (49 CFR 171.8): At least one of the pre-transportation functions specified in the definition section of 49 CFR 171.8 that are required to ensure the safe transportation of a hazardous material, including radioactive material.

Production Certificate: A document that is issued by the Third Party Approval Agency upon the satisfactory conclusion of container plan review, prototype approval, the production tests required by the approved test plan, the acceptance of the manufacturer’s quality control procedures and the survey of each container. These units, when considered acceptable to the Third Party Approval Agency, will be certified and Production Certificate issued. The Production Certificate when issued will list the serial numbers for each container.

Prototype Test Certificate: A document that is issued by the Third Party Approval Agency when they have verified all designs, calculations supporting the design and methods of construction for the freight container meeting the design considerations and the performance tests as required in the Agency's Rules of Certification. Prior to this document being issued the surveyor will witness the construction of each freight container, verify the materials of construction are as designated in the design drawings, verify fabrication techniques, such as. welding, and witness each test that is required in their Rules of Certification. This document is issued by the Third Party Approval Agency when a prototype container meets the requirements of the Rules of Certification based on the surveyor's observations and it has been determined that the prototype has passed the required tests.

Quality assurance (49 CFR 173.403): A systematic program of controls and inspections applied by each person involved in the transport of radioactive material which provides confidence that a standard of safety prescribed in this subchapter is achieved in practice.

Radiation level (49 CFR 173.403): The radiation dose-equivalent rate expressed in millisieverts per hour or mSv/h (millirems per hour or mrem/h). It consists of the sum of the dose-equivalent rates from all types of ionizing radiation present including alpha, beta, gamma, and neutron radiation. Neutron flux densities may be converted into radiation levels according to Table 1 in 49 CFR173.403 (definitions).

Radiation shield (ANSI N14.7): Material incorporated in packaging to reduce the intensity of radiation from the package. The radiation shield surrounds the contents and may or may not qualify as a containment system.

Routine conditions of transport (ANSI N14.7): Routine conditions of transport are incident free with no mishaps. Type A packages are required to demonstrate that they can withstand routine conditions of transport by meeting the requirements of 49 CFR 173.24, 24a, 24b, and 173.410.

Routine Conditions of Transport (RCT): RCT are quantitatively defined in the international regulations (TS-R-1, *Regulations for the Safe Transport of Radioactive Material*, and TS-G-1.1, *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*). The Federal Motor Carrier Safety Administration (FMCSA) in 49 CFR 393 provides requirements and associated acceleration factors that can be applied for domestic NCT considerations.

RCT International: The Regulations for the Safe Transport of Radioactive Materials (e.g., TS-R-1 and TS-G-1.1) define routine conditions of transport (RCT) as follows:

	Acceleration Factors		
Transport Mode	**Longitudinal**	**Lateral**	**Vertical**
Highway	2g	1g	2g up, 3g down
Rail	5g	2g	2g up, 2g down
Sea	2g	2g	2g up, 2g down

- Incident free transport conditions (TS-R-1, 106);
- Accelerations, vibration or vibration resonance (TS-R-1, 612); and Acceleration factors for package retention for RCT from TS-G-1.1 IV, Table IV are listed in the table below.

Appendix V of TS-G-1.1 discusses conveyance package retention. The following are excerpts from TS-G-1.1, Appendix V:

- Package retention systems only have to be designed to meet the demands of routine conditions of transport. Therefore, in normal or accident conditions of transport, the package is permitted, and may be required as part of the design, to separate from the conveyance by the breakage or designed release of its restraint in order to preserve the package integrity.
- The methods of retention should not cause the package to be damaged, or even stress components of the package or its retention system beyond yield, during routine conditions of transport.
- The requirement that the integrity of the package should not be impaired by overstressing in normal or accident transport conditions can be satisfied by the designer incorporating quantifiable weak links in either the package attachment points or in the tie-downs specified for restraint. See Figure 3.6 for freight container attachment points.
- The forces imposed on the package may be determined by multiplying the acceleration factors by the mass of the package. For vertical accelerations, the factors are those experienced by the package, not allowing for gravity.

RCT Domestic: For domestic transport the Cargo Securement Rules of the Federal Motor Carrier Safety Administration (FMCSA) provides relevant package securement requirements. Excerpts (in italics) from the FMCSA (49 CFR 393) are provided below.

- FMCSA has adopted new performance requirements concerning deceleration in the forward direction, and acceleration in the rearward and lateral directions, those cargo securement systems must withstand. Deceleration is the rate at which the speed of the vehicle decreases when the brakes are applied, and acceleration is the rate at which the speed of the vehicle increases in the lateral direction or sideways (while the vehicle is turning), or in the rearward direction (when the vehicle is being driven in reverse and makes contact with a loading dock).
- FMCSA requires that cargo securement systems be capable of withstanding the forces associated with following three deceleration/accelerations, applied separately:
– 0.8 g deceleration in the forward direction,
– 0.5 g acceleration in the rearward direction, and
– 0.5 g acceleration in a lateral direction.
– 0.2 g acceleration in a vertical direction

These values were chosen based on researchers' analysis of studies concerning commercial motor vehicle performance.

The Shipper has the responsibility for evaluating the securement of packages or components within the Freight Container. Packages and components need to remain in place, without changing position, and not incur damage under the routine conditions of transport.

Rules of Certification: A document that is produced by a Third Party Approval Agency that is used by those organization who wish to have a freight container (cargo container) approved by that agency who represents the competent authority of the country they represent. This document may have varying titles as described in the table below.

Third Party Approval Agency	Title of their "Rules of Certification"
American Bureau of Shipping	Rules of Certification of Cargo Containers
Bureau of Veritas	Rules for the Classification and Certification of Freight Containers
Lloyds Register	EMEA Container Certification Scheme
DET Norske Veritas	Rules of Certification of Freight Containers
Germanischer Lloyd	Rules for Classification and Construction

Shall, must, should, and may: For the purposes of this document, the word "shall" is used to denote a requirement which is supported by a standard or regulation; the word "must" is denotes a requirement that is used as part of a quotation; the word "should," denotes a recommendation; and the word "may," denotes permission (neither a requirement nor a recommendation).

Shipment/Consignment (ANSI N14.7): Any package, packages, or load of radioactive material presented by a consignor for transport.

Shipper/Consignor (ANSI N14.7): Any person, organization, or government that prepares a consignment for transport and is named as consignor in the transport documents.

Standard Freight Container: A freight container complying with ISO 1496-1, Series 1 *freight containers-Specification and testing*-Part 1*: General cargo containers for general purposes,* Edition 1990, as identified in 49 CFR 173.411(b)(6) and for purposes of this document. (Also see ISO 668 – Series 1 *Freight container - Classification, dimensions and ratings*.)

Commercial Process for Freight Container Certification

Sections from ANEX A of ISO 1496-1 have been copied and reproduced in this

The American Bureau of Shipping (ABS) has been designated as an authorized entity by the US Coast Guard (per 49 CFR 450, Subpart B) to ensure compliance with the International Convention for Safe Containers (CSC) requirements for the United States. Therefore, their process for freight container certification (i.e., ABS Rules for Certification for Cargo Containers) will be outlined in this Certification includes freight container design, design review, prototype and production testing, manufacturing controls and inspections, marking, and certification by the authorized authority. Periodic inspections and re-inspections (following repair or maintenance) required for continued CSC approval, in accordance with 49 CFR 452, will also be discussed.

1 Freight Container Certification Process

The certification process consists of a) the development of rules, guides, standards and other criteria for the design, construction and quality assurance of containers, materials, and equipment; b) the review of the design and survey during and after construction to verify compliance; and c) the issuance of certificates when such compliance has been verified. The rules, guides, and standards are developed by the specific bureau (e.g., ABS) and approved by committees made up of users, manufacturers, engineers, materials experts, operations and other technical/scientific personnel. The certification process is comprehensive and carried out by qualified personnel in accordance with the federal regulations. As such, the certification documentation should be fully adequate to demonstrate compliance to DOT requirements. Containers certified to the ABS rules of certification meet the CSC and ISO-1496-1 requirements.

1.1 Conditions of Certification

The requirements for freight container certification are determine by bureaus and approved by committees made up of experienced container manufacturers, users, marine/railroad/structural/materials engineers, ship builders, steel makers and other relevant technical experts. The conditions for certification consist of, but are not limited to, completion of the following:

- Compliance with specified rules, guides, standards, and other criteria for the design, testing and construction (e.g., CSC, ISO 1496-1);
- Review of container design, drawings and calculations;
- Use of appropriate materials of construction and equipment;
- Review of container plans for prototype design and performance testing;

- Review of quality programs, testing plans, procedures, and manufacturing facilities;
- Surveillance of prototype testing and production manufacturing (by bureau authorized inspectors); and
- Completion of reports documenting prototype testing and production fabrication.

Certification is granted when a bureau, through its reviews and surveillance, concludes that the conditions for certification have been satisfactorily met. Certification is a representation by the Bureau as to the structural fitness for the particular use or service in accordance with its Rules, guides and standards. Placement of a round ABS emblem (representing general service) signifies the container complies with the ABS Rules for Certification, which includes the CSC and ISO 1496-1 requirements.

1.2 Design Review

For new or modified freight container designs, a manufacturer is required to submit comprehensive information to the bureau for review. The submittal is to include a statement that the containers:

- will be built in conformance to the "Rules of Certification for Cargo Containers",
- will be manufactured under a quality control program acceptable to the bureau,
- will be available for inspection during manufacture and testing, and
- will be tested in accordance with prescribed procedures.

Additionally any changes in design, materials, or fabrication methods will not be made without written approval.

The information submitted varies depending on whether a new design series is being requested or whether additional units of an approved design or changes to an existing design are desired. These required documents are identified in Table 1 below.

Table 1. Documents to submit to bureau for design review

New Design Series*	Approved Design Series*	Changes to existing Designs*
Application of each new design series is to include the following plans and data.	Application of additional units to be certified to an approved design series is to include the following.	When changes are being made to an application or to an approved design series, include the following.
Application Form	Container Data Form	Container Data Form

Container Data Form	Data Form Supplement for Thermal Containers if applicable	Data Form Supplement for Thermal Containers if applicable
Material identification form		Design Comparison Table
Following drawings ▪ General arrangement ▪ Sub-assemblies ▪ Detail of components ▪ Markings, including data plates		Following Drawings ▪ Marking drawing – If owner has changed ▪ General Assembly ▪ Subassembly ▪ Detail drawing as appropriate showing any revision from original design ▪
Prototype Test Agenda		All changes will be reviewed and if the modifications are deemed significant retesting of those parts of the container affected by the modification may be required.
Quality Control Procedures – Required for each facility		
When the application includes a request for certification to governmental requirements, international conventions, or other standards, the submittal is to include the necessary information required for the reviews.		

**Information in Table 1 was extracted from the ABS Rules of Certification for Cargo Containers 1998*

Upon receipt of the documents identified under "New Design Series", the bureau will perform a thorough design review of drawings, calculations, test agenda, and quality control procedures provided by the manufacturer. Upon completion of the design review, which is based primarily upon the container meeting the design considerations in Section 1.5, the performance tests in Section 1.6 will be performed. The bureau will then allow the manufacturer to fabricate the freight containers that will be used for the performance tests in Section 1.6. During the manufacturing of these units, the bureau's surveyor inspects the use of materials of construction along with verifies welding processes, quality assurance program, and the testing of units.

1.3 Materials and Fabrication

Materials and fabrication details are included in the documentation required by the shipper of IP-2 and IP-3 radioactive material packages per 49 CFR 173.411(c). The bureau's freight container certification process specifically addresses materials and fabrication in Section 3 (ref). All structural materials will conform to an established specification or recognized national standard. Since the majority of freight containers are fabricated in countries outside the US, due notice is given to practices in the specific country.

The bureau verifies the acceptability of materials and the welding processes. Welding is to be carried out in accordance with recognized standards by qualified welders. The bureau's rules go into significant detail on welding details, qualifications, and tests. Bureau surveillance personnel review all weld procedures and perform surveillance during manufacture. Since freight containers are primarily all-welded construction (except for doors, etc.) the acceptability of materials and welding practices and procedures is given attention during reviews, testing and surveillance. (Joint types, orientations, and acceptance criteria)

1.4 Quality Control

The Bureau will approve all prototype and production manufacturing and testing facilities and carry out periodic audits. The principal freight container manufacturers submit quality control manuals to the Bureau which gives in detail those inspections and controls to be followed to assure the quality of the production units are comparable to that of the prototype. The required quality elements are listed below. The manufacturer must submit its QC manual to the Bureau for review in order that compliance may be verified with QC requirements of the ABS Rules for Certification. The manufacturing facility is subject to audit by the ABS surveillance personnel to confirm compliance with the QC procedures specified in the submitted manual. All changes or revisions to the QC manual including any procedural changes are to be submitted to the bureau for review.

The QC manual is to include the following elements:

- Description of Organization: Manufacturer's organization including management, purchasing, production, and QC functions.
- Materials Identification: methods are to be in place to control and identify all materials, including methods for welding electrode identification.
- Workmanship Quality: methods are to be in place to ensure consistently acceptable quality (e.g., jigs, fixtures).
- Control Records: procedures for maintaining records are to be adequate to assure identification of material and checks on workmanship.
- Fabrication QC Methods: welding procedures and inspection techniques used in fabrication are to be acceptable to the Bureau surveillance personnel. Special attention is given to ensuring adequacy of corner fittings and their attachment to the structural members.

1.5 Design Considerations

Freight containers are designed to be structurally sound and weather tight under multi-modal (highway, rail, marine) loading, transport and handling conditions. The main frame, corner fittings, sides and ends are to have sufficient structural strength to withstand, without significant permanent deformation, the static and dynamic loads imposed by lifting, stacking, impact, vibration, and racking loads encountered under normal service conditions as well as protect the cargo from the environment. The floor structure must be strong enough to support the payload under dynamic loading and concentrated forklift truck axle loads. The design considers the loads from each transport mode and terminal handling, expressed as accelerations. Marine transport imposes significant transverse loads on the containers due to the sway of the ship and the high stacking heights. Rail transport imposes significant longitudinal loads due to coupling and humping loads. Handling equipment that loads and unloads containers imposes significant vertical accelerations on the container. Overall the freight container is designed to withstand the maximum normal loads from all modes of transport and handling. This results in a robust structure that remains serviceable and does not undergo elastic deformation under normal service.

The freight container design features include four top and four bottom corner fittings which defines a rectangular box. The corner fittings are welded to the top, bottom, and end rails to form the frame of the FC. The corner fittings are to protrude slightly above the highest point of the roof and the bottom corner fittings protrude slightly below the plane of the bottom, so that when stacked the load can be fully supported at the corners. Other design features include forklift pockets and special lifting and cargo securing devices.

The design loads required by Freight Containers take into account the normal service conditions outlined above. The design loads required by the ABS Rules (include CSC and ISO-1496-1 considerations) are summarized below. Note – the design loads are statically applied to prototype containers as discussed in Section 1.6. For the bulleted items below: R = Gross Weight, P = Maximum Payload, T = Tare Weight.

- Corner Structure Loads – Stacking – to simulate stacking on a ship that is pitching and heaving: the corner structure is to have sufficient strength to allow stacking when transported by ship. Design load factor (static + dynamic) is 1.8 x 8 R (stacking 9 high) distributed among the four corner structures.
- Lifting Loads – to ensure top and bottom corner fittings and associated structures are capable of suspending a loaded container: Total weight of 2R, a) lifting vertically from top with each corner to carry ¼ the design load, b) lifting from 4 bottom corners at 45o angles to horizontal (for 20' container), and c) lifting from fork-lift pockets in vertical upward direction.
- Floor Loads – to ensure floor is capable of carrying loads imposed by loading vehicles and cargo: a) wheel: floor is to withstand concentrated loads imposed by lift truck front axle (two wheels) loading of 12,000 lbs. over an area not greater than 22 in2/wheel, and b) cargo: 2P uniformly distributed from side to side over any 10' of length.
- Floor and Rear Panel Loads – to ensure front and end panels can withstand cargo load forces resulting from rail coupling impacts or highway breaking: a) load of 0.4P uniformly distributed outward over the front and rear end panels, and b) transverse racking load of 33,700 lbs. applied at top of front and rear panel corners with bottom corners fixed.

- Side Panel Loads – to ensure side panels can withstand cargo load forces resulting from ship rolling or highway cornering: a) a load of 0.6P uniformly distributed over side walls in transverse direction (outward), and b) longitudinal racking load of 16,850 lbs. applied at each top corner of side wall with bottom corners fixed.
- Lashing – to simulate external forces transmitted to the corner fittings: concentrated loads applied individually or simultaneously to the corner fittings in the longitudinal, transverse and vertical directions.
- Roof Load – simulates two 220 lbs. workers on roof: a load of 440 lbs. uniformly distributed over a 2’ x 1’ area in a downward direction.
- Base Structure Loads – ensures base structure can withstand forces resulting from rail impacts: a load of 2R applied in a longitudinal direction through bottom apertures of the bottom corner fittings to simulate acceleration during rail car impact.
- Cargo Securing Devices (where provided) – to ensure anchor or lashing points can withstand inertial forces imposed by cargo in transit: concentrated load applied away from cargo securing device located inside FC, a) 2200 lbs. for anchor point in base structure, b) 1100 lbs. for lashing point in any other part of container (other than base).

1.6 Testing

C.1.6.1 Prototype tests

Full-sized prototype containers, manufactured to the same QC requirements as production containers, are tested to verify design adequacy. The test loads are primarily static to provide comparable and repeatable test data at reasonable costs. The test loads (described in 1.6.2) take into account the combined static and dynamic loads anticipated in service. Bureau surveillance personnel witness prototype tests. Dimensional measurements are taken before testing and retaken, along with weather tightness, upon completion of all structural tests.

Testing acceptance criteria: a) when the prescribed load is applied the container is not to exhibit significant permanent deformation or weakening; and b) after removal of the load the dimensions are to return to the original values within allowable tolerances and the unit is to be fully suitable for service.

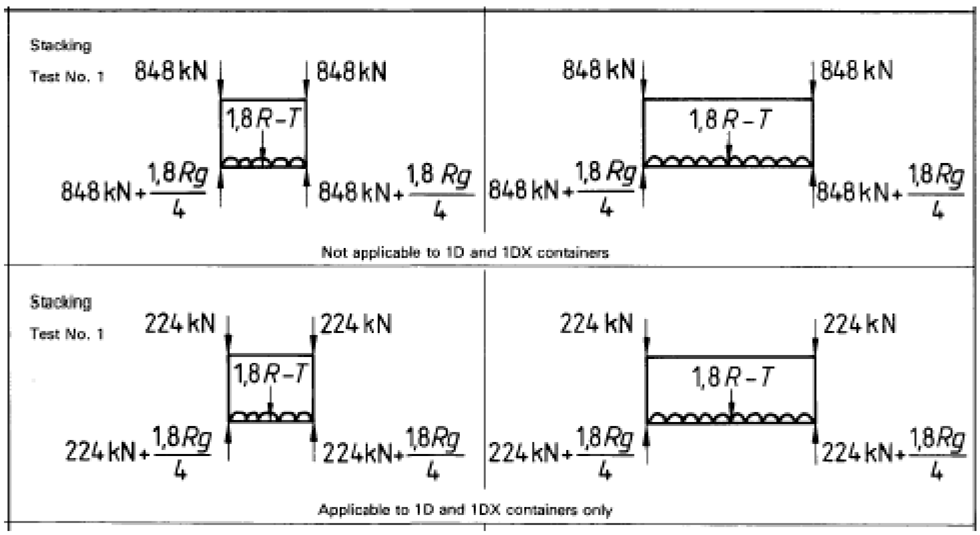
1.6.2 ISO-1496-1 tests

The ISO 1496-1 prototype tests are briefly paraphrased below. Compliance with these tests will generally satisfy the Design Requirements discussed in Section 5.4.1, meeting the ISO 1496-1, and are specifically the tests referred to in DOT 49 CFR 173.411(b)(6). It is noted that the CSC also contains testing requirements but they are slightly different than the ISO 1496 tests. A comparison of the differences between the ISO 1496-1 and CSC testing details is given in M. Note – for additional details on tests, see ISO 1496-1 Section 6. The first sentence of each test (except for test #12) provides the rational for structural test criteria excerpted from ISO TR 15070, Series 1 Freight Containers – Rationale for Structural Test Criteria. Other excerpts for each test below are taken from ISO 1496-1, Section 6.

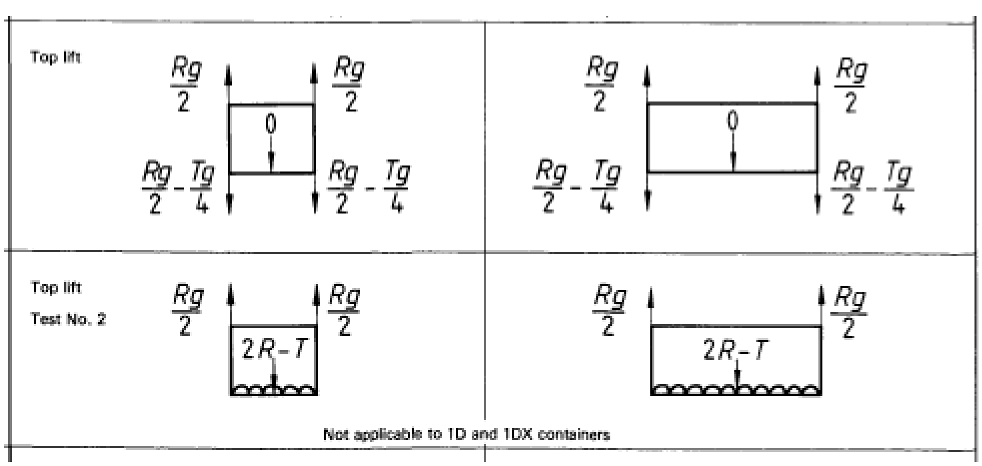
1. <u>Stacking</u> – The test is carried out to prove the ability of a fully loaded container to support a superimposed mass of containers, taking into account the conditions aboard ships at sea. The

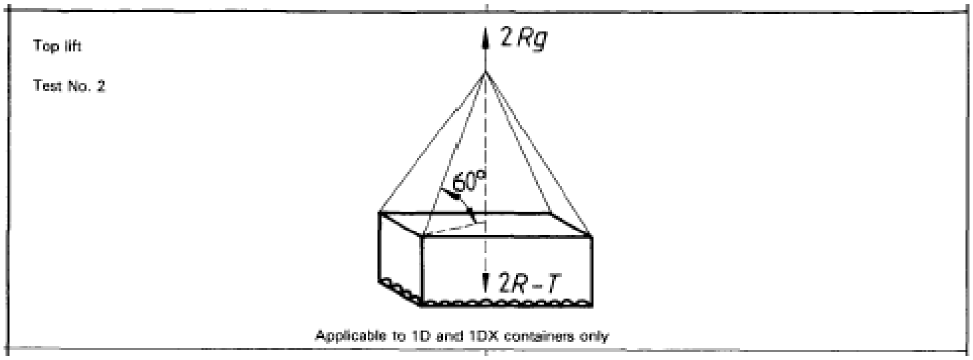
container shall be placed on four level pads, one under each bottom corner fitting and be floor of the container shall be uniformly loaded to a weight of 1.8R. The container shall be subjected to vertical force of 762,550 lbs. (nine-high stacking), applied to all four corner fittings simultaneously, or 381,275 lbs. to each pair of end fittings. Upon completion of the test, the container shall show neither permanent deformation nor any abnormality which will render it unsuitable for use.

Figure Definitions: R = Gross Weight, P = Maximum Payload, T = Tare Weight

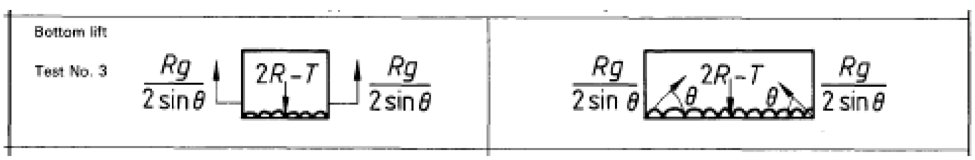


2. Lifting from the Four Top Corner Fittings – This test is carried out to prove the ability of a container, whether in a loaded or empty condition, to withstand being lifted vertically using its top corner fittings. It demonstrates the lifting capability not only of the top frame but also of the entire container frame and floor structure of the container. The container shall have a load uniformly distributed over the floor such that the combined weight of the container and payload is 2R and shall be lifted vertically from all top corners such that no significant acceleration or deceleration forces are applied. The container shall be suspended for 5 min. and then lowered to the ground. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.

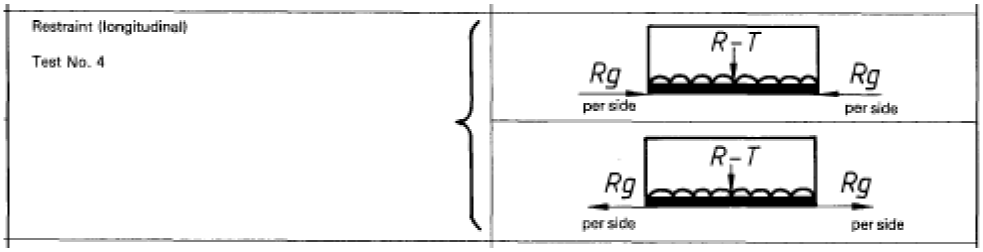




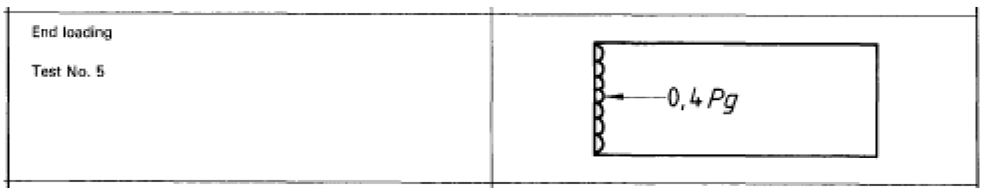
3. Lifting from Bottom Corners – This test is carried out to prove the ability of a container, whether in a loaded or empty condition, to withstand being lifted using the bottom corner fittings, in accordance with ISO 1161, Series 1 Freight Containers – Corner Fittings - Specifications, via slings which transmit the lifting force from the bottom corner fittings obliquely to a single transverse spreader beam. The container shall have a load uniformly distributed over the floor such that the combined weight of the container and payload is 2R and shall be lifted from the side apertures of all four-corner fittings in such a way that no significant acceleration or deceleration forces are applied. Lifting forces shall be applied at 45º to horizontal for a 20' container. The container shall be suspended for 5 min. and then lowered to the ground. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.



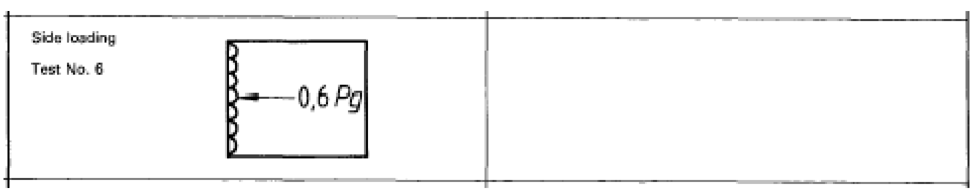
4. Restraint (longitudinal) – This test is carried out to prove the ability of a container to withstand longitudinal external restraint under dynamic conditions of railway operations. The container shall have a load uniformly distributed over the floor such that the combined weight of the container and payload is R, and be secured to anchor points through the bottom apertures of the bottom corner fittings at one end of the container. A force of 2R shall be applied horizontally to the container through the bottom apertures of the other bottom corner fittings, first towards and then away from the anchor points. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.



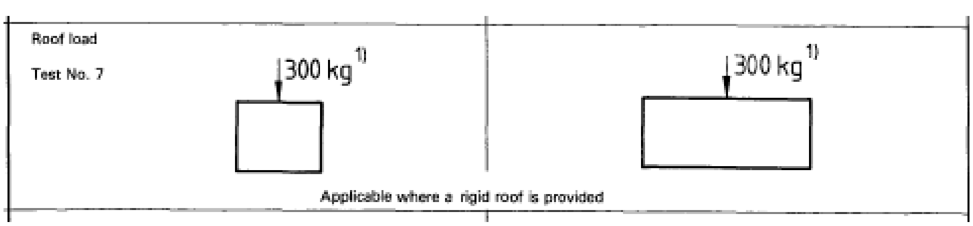
5. Strength of End Walls – This test is carried out to prove the ability of the end walls of a container to withstand the forces caused by the cargo under the dynamic conditions of railway operations. The container shall be subjected to an internal loading of 0.4P uniformly distributed over the wall. Both the blind end and door ends shall be tested. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.



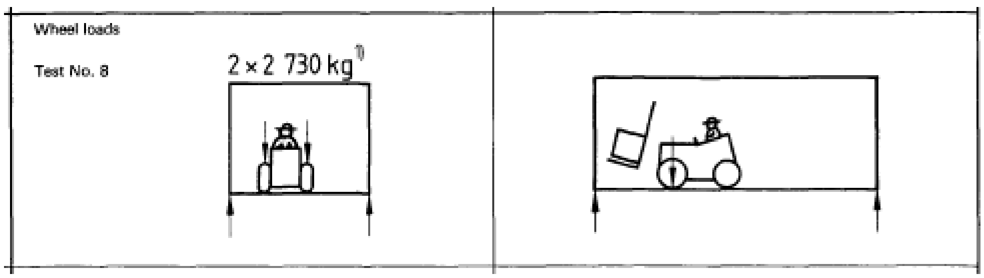
6. Strength of Side Walls – This test is carried out to prove the ability of the sidewalls of a container to withstand the forces caused by cargo under dynamic conditions of ship movement. Each side of the container shall be subjected to a uniformly distributed loading of 0.6P. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.



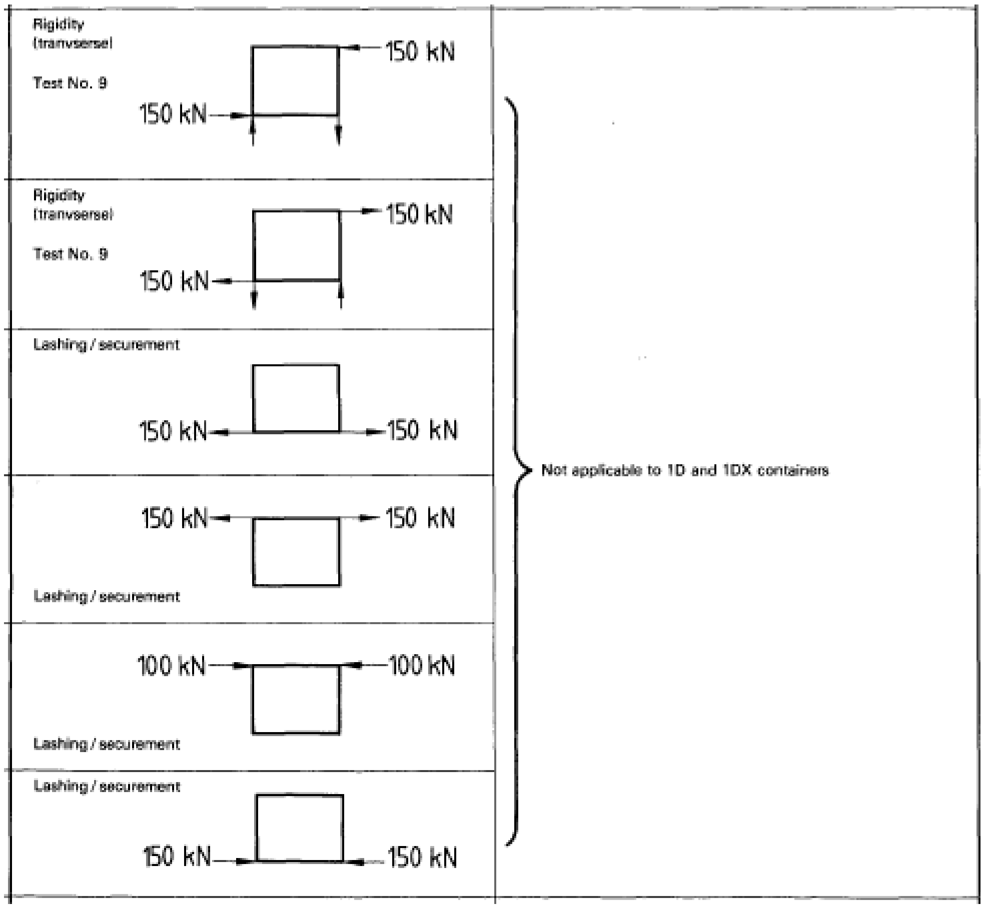
7. Strength of Roof – This test is carried out to prove the ability of the rigid roof of a container, where fitted, to withstand loads imposed by persons walking on it. A load of 440 lbs. shall be distributed over an area of 1' x 2' located at the weakest area of the rigid roof of the container. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.



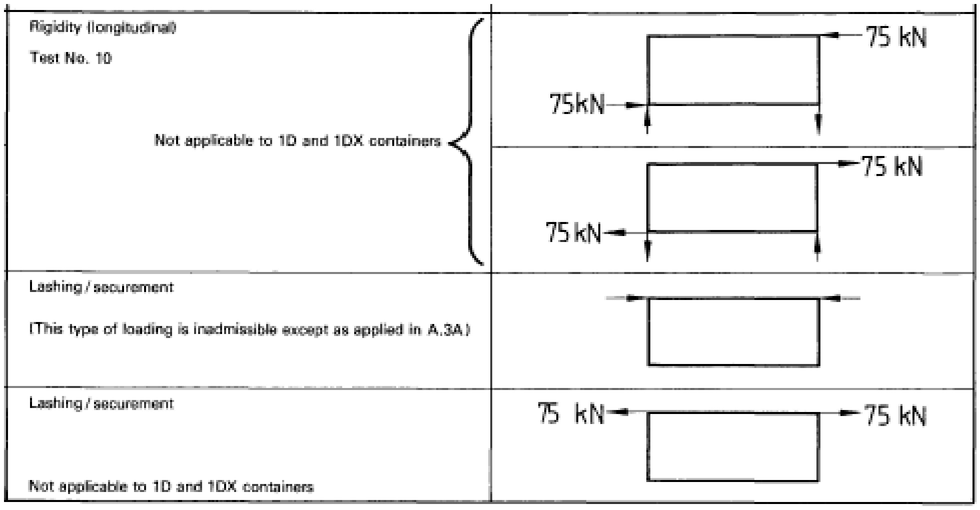
8. Floor Strength – This test is carried out to prove the ability of the floor of a fixed container to withstand concentrated dynamic forces imposed by wheeled vehicles placing and removing cargo. The test shall be performed using a test vehicle equipped with tires with an axle load of 12,000 lbs. (6,000 lbs. on each of two tires). The footprint (area) shall be no more than 22 in^2 per tire. The test shall be made with the container resting of four level supports under its four bottom corner fittings, with its base structure free to deflect. The test vehicle shall be driven over the entire floor area. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.



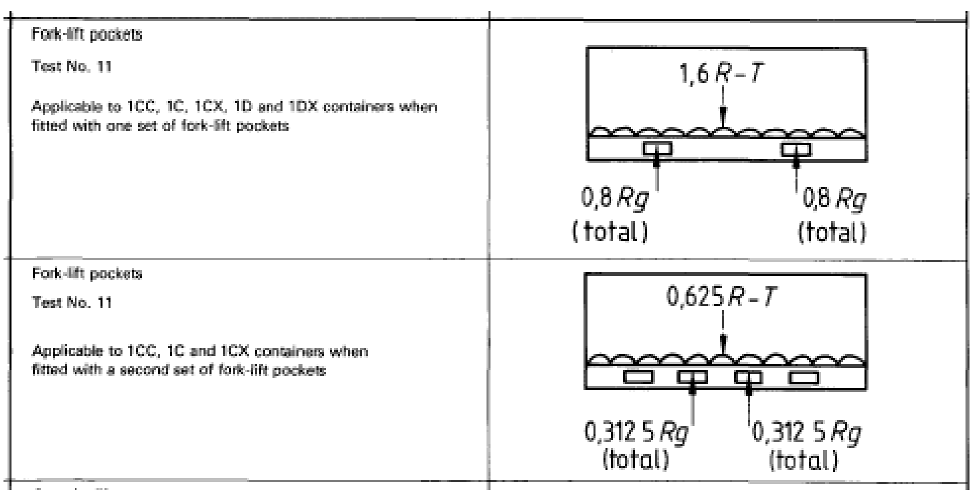
9. Rigidity (transverse) – This test is carried out to prove the ability of a container to withstand transverse racking forces resulting from ship movement. An empty container shall be placed on four level supports, one under each corner fitting and be restrained against lateral and vertical movement by anchor devices acting through the bottom apertures of the bottom corner fittings. Lateral restraint shall be provided only at a bottom corner fitting diagonally opposite to and in the same end frame as a top corner fitting to which the force is applied. A force (at right angles to long axis) of 33,700 lbs. shall be applied to each of the top corner fittings on one side of the container parallel both to the base and in the planes of the ends of the container. The forces shall be applied first towards and then away from the top corner fittings. The sideways deflection of the top of the container under full transverse loading shall not cause the sum of the changes in length of the two diagonals to exceed 2 3/8 inches. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.



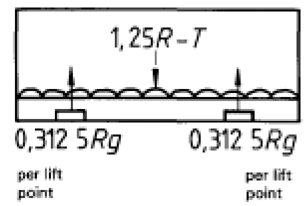
10. Rigidity (longitudinal) – This test is carried out to prove the ability of a container to withstand longitudinal racking forces resulting from ship movement. An empty container shall be placed on four level supports, one under each corner fitting and be restrained against lateral and vertical movement by anchor devices acting through the bottom apertures of the bottom corner fittings. Longitudinal restraint shall be provided only at a bottom corner fitting diagonally opposite to and in the same side frame as the top corner fitting to which the force is applied. A force of 16,850 lbs. shall be applied to each of the top corner fittings on one end of the container in lines parallel both to the base of the container and to the planes of the sides of the container. The forces shall be applied first towards and then away from the top corner fitting. The longitudinal deflection of the top of the container with respect to the bottom of the container, under full test load shall not exceed 1 inch. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met.



1. Lifting from Fork-Lift Pockets (where fitted) – This test is carried out on any container which is fitted with forklift pockets to demonstrate its ability to be lifted by forklift equipment (40-ft freight containers may not have forklift pockets). The container shall have a load uniformly distributed over the floor in such a way that the combined weight of the container and payload is 1.6R and it shall be supported on two horizontal bars each 8 inches wide, projecting 72 inches into the forklift pockets. The container shall be supported for 5 minutes and then lowered to the ground. A second test shall be applied to the (additional) inner pockets, except that the combined weight of the container and payload shall be 0.625R and the bars shall be placed in the inner pockets. Upon completion the container shall show neither permanent deformation nor any abnormality, which will render it unsuitable for use, and the dimensional requirements shall be met



2. Lifting from the Base at Grappler Arm Positions (where fitted) – Grappler arms are infrequently used today. See ISO-1496-1 for details of tests.

Grappler lift Test No. 12 Applicable to all sizes when fitted with grappler arm lift positions	

3. Weatherproofness – This test is carried out to prove the ability of a container to remain watertight after a stream of water has been applied on all external joints. A stream of water shall be applied on all exterior joints and seams of the container. The nozzle shall be held at a distance of 5 feet from the container and be moved at a speed of 4 inches per second. Upon completion of the test, no water shall have leaked into the container.

1.6.3 Production tests

Each freight container that is manufactured for use is dimensionally and weather tight tested by the manufacturer. A pull test is also performed on each corner post assembly. If inspection personnel deem quality control procedures adequate, the pull test may be performed on one container from each lot of fifty (50) containers. The Bureau surveillance personnel witness representative production tests during manufacturing.

1.7 Marking

Each container (approved by ABS) is permanently marked by the manufacturer with the following information:

- Manufacturer's name and address,
- Manufacturer's serial number,
- Month and year of manufacture,
- American Bureau of Shipping emblem (or other third party emblem as applicable),
- Maximum gross weight,
- Tare,
- Payload, and
- Design type number
-

The International Convention for Safe Containers (CSC) plate is required for international shipment in accordance with 49 CFR 450.1. Note: the CSC plate and associated periodic inspections, are not required for domestic use of freight containers nor are they required for use of freight containers as Type IP-2 or Type IP-3 packagings in accordance with 49 CFR 411(b)(6). The CSC plate contains the following information:

- Country of Approval Reference,
- Date (month and year) of manufacture,
- Manufacturer's identification number of the container,

- Maximum operating gross weight (kg and lb),
- Allowable Stacking Weight for 1.8g (kg and lb),
- Transverse Racking Test Load Value (kg and lb),
- End wall strength (only if end walls are designed to withstand a load of less than 0.4 times maximum permissible payload (i.e., 0.4P),
- Side wall strength (only if side walls are designed to withstand a load of less than or greater than 0.6 times maximum permissible payload (i.e., 0.6P), and
- First maintenance examination date (month and year) for new containers and subsequent maintenance examination dates (month and year) if plate is used for this purpose.

Typical securement systems consist of blocking, bracing, and tie-downs. The packaging content (e.g., components, bags, drums, boxes, piping, tanks) shall withstand static shipping forces due to the weight, density, and stacking of the content, and dynamic shipping forces due to vibration, jolting, and accelerations arising from changes in direction, starting, and stopping. The “1g” is defined as the acceleration due to gravity or in practical terms, 1g is equivalent to the weight of the item.

For domestic shipping, 49 CFR Chapter III, Federal Motor Carrier Safety Regulations, Part 393, Parts and Accessories Necessary for Safe Operation, Section 102, *What are the Minimum Performance Criteria for Cargo Securement Devices and Systems?* identifies that accelerations (0.8 g forward, 0.5g rearward, and 0.5g lateral) per Table 7-1, may be used to evaluate securement systems. Other requirements , such as those stated in 49 CFR 393, Section 106, *What are the General Requirements for Securing Articles of Cargo?* may be considered when determining load securement systems.

Maximum Forces Acting on a Freight Container During Transport

Force	***Road Transport**	**Rail Transport Subject to Shunting**	**Rail Transport Combined**
Forward Acting Force	0.8g	4.0g	1.0g
Backward Acting Force	0.5g	4.0g	1.0g
Sideways Acting Force	0.5g	0.5g	0.5g
1g = 9.81 m/s^2 *49 CFR 393.102 **Container Handbook, online http://www.containerhandbuch.de/chb_e/stra/index.html			

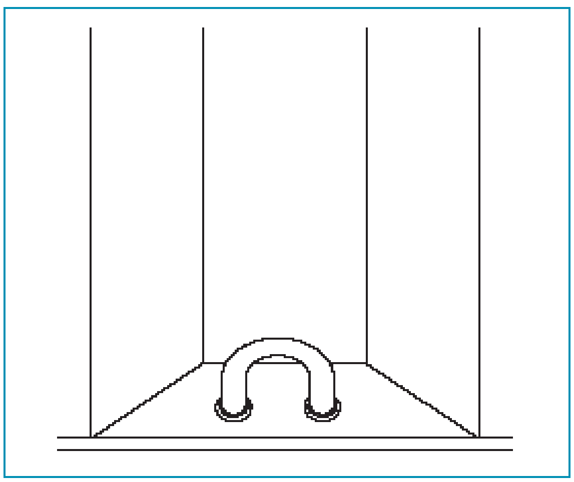
Example: What are the dynamic shipping forces on a 1000 pound (lbs.) component that needs to be secured within a freight container when transported on a road?

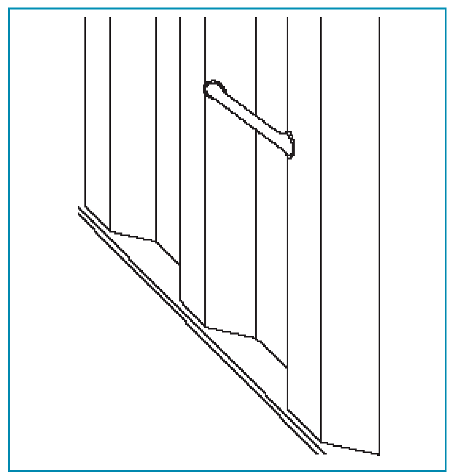
Answer: Using the "g-value" accelerations from Table 7-1, the resulting forces acting on the component are calculated in the bullets below. These forces shall be resisted by the securement system so that the component does not move. In accordance with 49 CFR 393.102, the securement system shall be sized to withstand these shipping forces to keep the component from moving:

- Forward (breaking): 1000 lbs. x 0.8g = 800 lbs.
- Rearward (acceleration): 1000 lbs. x 0.5g = 500 lbs.
- Lateral (cornering): 1000 lbs. x 0.5g = 500 lbs.

Shipping forces in rail transport can be much higher due to switching operations as shown in Table 7-1 and in APPENDIX P, Section 2.3.5. It is recommended that you carefully evaluate the securement system for keeping radioactive materials stationary within freight containers whenever shipping by rail.

One caution is if any additional anchor points are added (see Figure 7-2) for load securement to the inside of the freight container, an evaluation will need to be performed to ensure compliance with ISO 1496-1 design and testing requirements.





***Freight container Anchor Points are attached to frame rails (left) and Lashing Points to other Freight Container components (right) for load securement*[2]**

Stress Analysis of Top Fitting, Lifted with Twistlock Lifting Device

The top fitting is loaded in shear by the twistlock lift device, and has a shear area as depicted in Figure 1. Refer to Figures F-2 and F- 4 for the top corner fitting and twistlock connector configuration.

Shear Stress at Top of Fitting

Applied load = Total supported weight (W) / 4 fittings = W/4 lbs. per fitting, for vertical lift at top fittings

Shear stress $S_s = \frac{P}{A_s} = \frac{W}{4 \cdot A_s}$

For pure shear, the maximum equivalent tensile stress is equal to twice the shear stress = $2S_s$.

The factor to yield (S_y) is:

Shear Stress Factor = $\frac{S_y}{2 \cdot S_s}$

The shear stress factor must be greater than or equal to 3.

Example, using the dimensions provided in ISO 1161, Annex B (twistlock) and Figure F- 2 (top corner fitting):

Width of slot in fitting: 2.5 in

Twistlock head dimensions: 3 7/8 x 1 3/16 in

Overlap per side = (3.875 – 2.5) / 2 = .6875 in

Wall thickness of top of fitting = 1.125 - .0625 = 1.0625 in

Shear area (adjusted for 5/16" chamfers) A_s = 1.0625 * (2*(.6875)+1.188) – (.3125)*(.3125) = 2.63 in^2 per side (= 5.25 in^2 total)

Assume the container has a weight of 67,200 lbs. The shear stress is:

$$S_s = \frac{W}{4 \cdot A_s} = \frac{67{,}200 \text{ lb}}{4 \cdot \left(5.25 \text{ in}^2\right)} = 3200 \text{ psi}$$

Assume the corner fitting has yield strength of 39,000 psi. The shear stress factor is:

$$\text{Factor} = \frac{S_y}{2 \cdot S_s} = \frac{39{,}000\ \text{psi}}{2 \cdot (3200\ \text{psi})} = 6.1 > 3$$

Bearing stress between the twistlock and upper fitting:

Bearing area = 2*(.6875)*(1.188) = 1.64 in^2

$$\text{Bearing stress} = \frac{16{,}800\ \text{lb}}{1.64\ \text{in}^2} = 10{,}250\ \text{psi}$$

The bearing stress is evaluated per the requirements of ASME BTH-1[2], Equation 3-38, which provides an allowable bearing stress equal to 1.5 * S_y / (Design Factor).

$$\text{Factor to Yield: } F = \frac{39{,}000\ \text{psi}}{10{,}250\ \text{psi}} = 3.8 > 3$$

Top Fitting to Corner Post / Side Rail Weld Stresses

The top fitting is welded to the adjacent corner post and side rail(s) using fillet welds. Lift loads are transmitted through the welds, loading the post in tension and the side rails in shear. It is assumed that the side rails at open ends of the container do not react to the lift loads due to their comparatively low stiffness. All welds are assumed to be loaded in shear. It is assumed that the line of action of the lift loads acts through the center of the weld group consisting of the post and side rail welds. Based on this assumption, no net bending or torsional loads act on the weld group, which attaches the fitting to the post and side rails.

From the geometry of the attached post and side rails, the total length of weld, L_w, can be determined. Assume all welds are of the same material (S_y) and weld size (t_w). The stress in the weld is:

$$S_{weld} = \frac{\text{Load}}{.707 \cdot t_w \cdot L_w}$$

Since the welds are assumed to be loaded in shear, the allowable stress is S_y / 2. The factor to yield is calculated as:

$$\text{Factor} = \frac{S_y}{2 \cdot S_{weld}} \geq 3$$

Base Metal at Top Fitting to Corner Post / Side Rail Weld

The base metal at the welded connections must be checked to ensure sufficient margin exists. The minimum material yield strength of the fitting, post, and side rails should be used for this calculation. The effective area is the same as the weld area, except the full weld thickness, t_w is applicable. It is conservatively assumed that the base metal at the welds is loaded in shear. The relations are:

$$S_{Base} = \frac{Load}{t_w \cdot L_w}$$

$$Factor = \frac{S_y}{2 \cdot S_{Base}} \geq 3$$

Failure Mode Under Excessive Load Application

The factor to yield for the "Top Fitting to Corner Post / Side Rail Weld Stresses" evaluation shall be greater than that for the "Shear Stress at Top of Fitting" evaluation. This is accomplished by ensuring the weld size and length which attaches the corner fitting to the post and rails is sufficient to provide the required margin to yield. Therefore, if an excessive load were applied to the lifting attachments during a lift using the top corner fittings, the failure mode would be shear through the ISO corner fitting. This would not impair the ability of the package to perform its intended function (e.g., containment of particles and radiation shielding).

Bottom Fitting, Lifted With Rotary Lug Lift Device

Lifts from the bottom fittings are commonly performed using a rotary lug lift device. [3] Refer to Figures F-3 and F-5a, -5b for the bottom corner fitting and rotary lug lift device configuration. The rotary lug lift device fits into the long container side slot for lifting, and the lug is turned 90 degrees after installation to lock it in place. When loaded, the lug bears against the upper inside surface of the bottom fitting, and the pin bears against the upper edges of the side slot (see Figure F-1). The bottom fitting is not evaluated for shear loads, as no shear failure plane exists for this lift configuration. However, the lug bears against the free edge of the slot in the bottom fitting, and bearing stresses are evaluated below.

For a minimum sling angle of θ from horizontal, the lift load is resolved into components below:

Lifted load per fitting = Vertical load = F_v

Horizontal component: $F_H = \frac{F_V}{\tan\theta}$

The rotary lug lift device has a turned down section which bears against the side and top edges of the slot, and a t-head which bears against the inner top surface of the fitting. The configuration of the lift device is such that the t-head is subjected to most of the vertical load component, and the turned down section of the lug is subjected to most of the lateral load component. Bearing stresses are determined for both regions of the fitting.

Inside edge of slot:

$$A_{b\_slot} = D \cdot t$$

Where D is the pin diameter and t is the thickness of the fitting.

$$S_{b\_slot} = \frac{F_H}{A_{b\_slot}}$$

The bearing stress is evaluated per the requirements of ASME BTH-1, Equation 3-38, which provides an allowable bearing stress equal to 1.5 * S_y / (Design Factor). Solving in terms of the design factor gives:

$$DF_{slot} = \frac{1.5 \cdot S_Y}{S_{b\_slot}} > 3$$

Upper inside surface of fitting:

$$A_{b\_upper} = w \cdot h$$

$$S_{b\_upper} = \frac{F_V}{A_{b\_upper}}$$

The design factor is calculated the same as above for the slot:

$$DF_{upper} = \frac{1.5 \cdot S_Y}{S_{b\_upper}} > 3$$

<u>Bottom Fitting to Corner Post / Side Rail Weld Stresses</u>

See discussion in Section 2.1.1, under "Top Fitting to Corner Post / Side Rail Weld Stresses."

<u>Base Metal at Bottom Fitting to Corner Post / Side Rail Weld</u>

See discussion in Section 2.1.1, under "Base Metal at Top Fitting to Corner Post / Side Rail Weld."

<u>Failure Mode Under Excessive Load Application</u>

If an excessive load were applied to the lifting attachments during a lift using the bottom corner fittings, the failure mode is indeterminate. It is shown through calculations that the bottom corner fittings and their attachment welds are robust and can withstand lift loads with significant margin. If significant overload occurred, some deformation of the fitting wall would occur, and possible disengagement of the rotary lift device from the fitting could result. In addition, buckling of the container frame is expected at significant overload conditions. Analysis to determine the magnitude of load required for these failure modes is beyond the scope of this document.

References:

1. ISO 1161, Series 1 Freight Containers – Corner Fittings – Specification, 1984
2. "Design of Below-the-Hook Lifting Devices", ASME BTH-1-2005