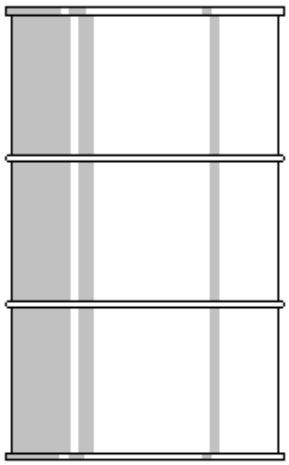

Hazardous Materials Packaging

Testing Procedures for Steel Drums

Prepared by

Industrial Steel Drum Institute

REUSABLE INDUSTRIAL PACKAGING ASSOCIATION

January 2014

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I. Introduction

The procedures outlined in this packaging testing manual result from a collaboration between the members of the Industrial Steel Drum Institute (ISDI) and the Reusable Industrial Packaging Association (RIPA). ISDI's membership is comprised of manufacturers of new industrial steel drums while the members of RIPA primarily remanufacture and recondition steel drums for reuse. A broad range of raw material and component suppliers serves both association memberships.

This manual was developed as a guide designed to assist members of the two associations in performing mandated tests that will qualify steel drums for use in shipping hazardous materials (*aka* "dangerous goods").

These tests were largely developed by the UN Subcommittee of Experts on the Transport of Dangerous Goods which meets regularly to develop recommendations concerning the transport of hazardous materials. The U.S. Department of Transportation is the regulatory body in the U.S.A. that adopts UN Recommendations and/or adopts its own policies as may be deemed necessary. Drums that pass the required design qualification tests are often referred to as "UN-rated drums". The U.S. regulations are known as the " Hazardous Materials Regulations" (HMR) and are codified as 49 CFR 105-190.

ISDI and RIPA members believe that container safety is a continuous improvement process that begins with proper container testing. This manual provides guidance on packaging testing procedures and methods that will lead to improved packaging performance in transportation. Some of the methods recommended here are based on years of professional experience and are used to supplement the basic regulatory directives.

ISDI and RIPA acknowledge that packaging testing is not an exact science, and that test procedures vary somewhat between laboratories even within the same company. However, this manual of recommended procedures will lead to greater uniformity of testing procedures which, in turn, will improve packaging transportation safety.

II. Disclaimer

In furnishing this information, ISDI and RIPA make no warrranties or representations, either expressed or implied, with respect to the completeness of the information contained in this manual; nor do the two associations assume any liability resulting from the use of or reliance upon any information, procedure, conclusion, or opinion contained in this guide.

ISDI and RIPA assume no responsibility for maintaining the data contained herein on a current basis or for notification of changes, additions or terminations.

Moreover, all photos and illustrations in this document are only representations. They are not to scale and are intended to be used for concept only.

Additionally, appendices in this document also are for information purposes only.

Contact the Office of Hazardous Materials Safety (OHMS), Pipeline and Hazardous Materials Safety Administration (PHMSA), in the U.S. Department of Transporation for formal interpretations of the Hazardous Material Regulations at (800) 467-4922 or www.phmsa.dot.gov/hazmat.

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III. Definitions of Terms 49 CFR §171.8

Non-Bulk Packaging
Maximum capacity of 450 L (119 gallons) or less for liquids
Maximum net mass of 400 kg (882 lbs) or less for solids

Bulk Packaging
Maximum capacity greater than 450 L (119 gallons) for liquids
Maximum net mass greater than 400 kg (882 lbs) for solids

Composite Packaging
A packaging consisting of an outer and inner receptacle, so constructed that the inner receptacle and the outer packaging form an integral packaging. Once assembled it remains thereafter an integrated single unit; it is filled, stored, shipped and emptied as such.

Gross Mass
The weight of a packaging plus the weight of the contents

Hazard Class
The category of danger assigned to a hazardous material under the definition criteria of 49 CFR Part 173 and the provisions of the hazardous material Table §172.101.

Hazardous Material
A Substance or material, including a hazardous substance, which has been determined by the Secretary of Transportation (DOT) to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce.

Hazmat Employee
A person employed by a hazmat employer and who in the course of employment directly affects hazardous materials transportation safety.

Liquid
A material that has a vertical flow of over 2 inches (50 mm) within a three minute period, or a material having one gram or more liquid separation, when determined in accordance with the procedures specified is ASTM D 4359-84.

Packing Group §172.101

Packing Group	Hazard Class	Marking on Packaging
Packing Group I	Great Danger	X
Packing Group II	Medium Danger	Y
Packing Group III	Minor Danger	Z

Closure Notification §178.601 (b) & §178.2 (c)
It is the responsibility of the packaging manufacturer, distributor and the person who offers a hazardous material for transportation to perform assembly functions, or provide written assembly instructions, to assure that each package is capable of passing the prescribed performance tests.

Flash Point
The minimum temperature at which a substance gives off flammable vapors which, in contact with sparks or flame, will ignite (§173.121).

Regulatory Agencies

DOT	U.S. Department of Transportation
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
UNCOE	United Nations Subcommittee of Experts

IV. Testing and Recordkeeping, General

Introduction

It is the responsibility of the container manufacturer (or "re-manufacturer"*) to perform and document design qualification testing, periodic retesting, and "production testing" in accordance with 49 Code of Federal Regulations ("CFR") Part 178 Subpart M – *"Testing of Non-Bulk Packagings and Packages"*. Through the testing and marking of packagings, each manufacturer and remanufacturer certifies that the packaging "design type" is capable of passing the prescribed tests.

All test records are to be kept at each location where the packaging is manufactured (or *"re-manufactured"* *) and at each location where design qualification tests are conducted for as long as the packaging is produced and for at least two years thereafter. All test records must be made available to the U.S. Department of Transportation (DOT) and/or a packaging user upon request.

Each packaging must be manufactured and assembled so as to be capable of successfully passing the prescribed tests.

Manufacturers and remanufacturers that perform the testing themselves are referred to as "self-certifiers". Alternatively, packaging manufacturers may use a third-party commerical testing facility to perform the design qualification tests and/or the annual, periodic retests.

ASTM has issued three stantdards which may also be referenced when perfoming UN Testing:

ASTM D 4919; Standard for Testing Hazardous Materials Packaging
ASTM D 7660: Standard Guide for Conducting Internal Pressure Tests onUnited Nations (UN) Packagings
ASTM D 7887: Standard Guide for Selection of Substitute, Non-hazardous, Liquid Filling Substances for Packagings Subjected to United Nations Performance Tests

Shipper Responsibility

It is the responsibility of the shipper, not the container manufacturer or reconditioner, to select the proper packaging for each hazardous material to be transported. The shipper determines that the packaging is produced and assembled in accordance with 49 CFR 178 Subpart M. The shipper may rely upon the markings applied by the packaging manufacturer or reconditioner as assurance that the packaging meets the relevant requirements.

* "Re-manufacturing" occurs when a drum is converted from one deisgn type to another, such as when converting a closed-head drum to an open-head drum; or when converting a non-UN drum to UN (hazmat) status. All rules on testing for manufacturing apply to re-manufacturing.

Definition of Packaging Design Type
(49 CFR 178.601)(g)(8)

This is the description that represents each unique packaging type.

For steel drums with a capacity greater than 50 L (13 gallons), a change in any one of the following design elements constitutes a different drum "design type" requiring all design qualification tests (i.e., "full design type testing")

(1) The packaging type and category of the original drum and the remanufactured drum, i.e., 1A1 or 1A2
(2) The style, (i.e., straight-sided or tapered)
(3) The rated(marked) capacity and outside dimensions; except if the change is 25% or less than the original type);
(4) The physical state for which the packaging was originally approved (e.g., tested for solids or liquids)
(5) An increase in the marked level of performance of the original drum (i.e., to a higher packing group, hydrostatic test pressure, or specific gravity to which the packaging has been tested)
(6) Type of side seam welding
(7) Type of steel
(8) An increase greater than 10% or any decrease in the steel thickness of the head, body, or bottom
(9) End seam type, (e.g., triple or double seam)
(10) A reduction in the number of rolling hoops (beads) which equal or exceed the diameter over the chimes
(11) The location, type or size, and material of closures (other than the cover of UN 1A2 drums)
(12) The location (e.g., from the head to the body), type (e.g., mechanically seamed or welded flange), and materials of closure (other than the cover of UN 1A2 drums)

(13) For UN 1A2 drums:
(A) Gasket material (e.g., plastic), or properties affecting the performance of the gasket;
(B) Configuration or dimensions of the gasket;
(C) Closure ring style including bolt size (e.g., square or round back, 0.625 inches bolt); and
(D) Closure ring thickness,
(E) Width of lugs or extensions in crimp/lug cover.

The design qualification test is not applicable for containers shorter than the original design as long as all other construction is identical. For example, a certification for a 208 liter (55 gallon) drum is valid for 197 liter (52 gallon) drum made on the same diameter. 49 CFR 178.601 (c)(4)(v)

Closure Notification (*aka* Closure Instructions) 178.2

Closure Notifications (aka "closure instructions") are a regulatory requirement when providing hazmat packagings. They also should be followed closely when preparing packages for design-type qualification testing and periodic re-testing under the regulations and under this manual.

(1) It is the shipper's responsibility to assemble the container for shipment in accordance with the manufacturer's, distributor's or reconditioner's closure instructions.
(2) A packaging manufacturer, distributor or reconditioner must provide each person to whom a packaging is transferred written instructions on proper closing of the container (closed in the same manner as it was prepared for testing), including:
- All requirements (for closing) not met at the time of transfer;
- Information about closures that must be used, including gaskets, sufficient to ensure the closed packaging can pass the design tests;
- Closing procedures;
- Instructions of sufficient clarity to provide for "consistent and repeatable" means of closure; and,
- Other relevent guidance to ensure safety by various modes of transport.

(3) Closure instructions must be retained by the manufacturer or distributor for at least 365 days.
(4) Closure instructions must be made available to DOT upon request.
(5) The instructions can be provided to shippers by "push" electronic means (e.g., e-mail or CD) but cannot be simply posted on a website. Closure Instructions must be capable of being printed.

Design Type Qualification: Applicable Tests

To determine the capabilities of a container, the following design-qualification tests are performed on the initial design type. Packagings qualified for only solids need not be tested for hydrostatic pressure or leakproofness,

- Drop
- Stacking
- Hydrostatic
- Leakproofness (w/ closures in place)
- Vibration *

(*49 CFR178.608 states that each packaging must be capable of withstanding the vibration test procedure; actual performance of the test is not required.)

Periodic Retesting

To ensure steel drums are manufactured in conformance with the original design, periodic retesting is performed on an annual basis. The full battery of design type tests (see above) must be run.

Production Testing

The following tests must be performed on every packaging produced.

- Leakproofness (for liquids packagings). Closures need not be in place for testing. However, vented closures must be replaced or sealed.
- Chime cut – On the initial drum from each production run and after any change in chime seamer. (Required only if the solution-over-partial-seams test method is used for leakproofness: 49 CFR Part178 Appendix B, Option 4)

Test Reports

Each person certifying compliance of a packaging design type (manufacturer or re-manufacturer) must maintain a copy of the test report. DOT requires that a test report, at a minimum, include the following information:

(1) Name and address of the test facility;
(2) Name and address of the applicant (where appropriate);
(3) A unique test report identification;
(4) Date of the test report;
(5) Manufacturer of the packaging;
(6) Description of the packaging design type (e.g. dimensions, materials, closures, thickness, etc.), including methods of manufacture (e.g. blow-molding), and which may include drawing(s) and photograph(s);

(7) Maximum capacity;
(8) Characteristics of test contents, e.g. viscosity and relative density for liquids and particle size for solids;
(9) Test descriptions and results; and,
(10) Signed with the name and title of the signatory.

Reports must be maintained at each location where where the packaging is manufactured or remanufactured and each location where the design qualification tests are conducted, for as long as the packaging is produced and at least two years thereafter, and at each location where the periodic retests are conducted until such tests are successfully performed again and a new test report produced. In addition, a copy of the test report must be maintained by a person certifying compliance with the regulations. Reports must be made available to a user of the packaging or a U.S. DOT representative upon request.

V. 1A1 Closed-Head Steel Drum Liquids

1A1 for Liquids

Sample Selection – Packaging manufacturer randomly selects 20 packagings that are representative of those produced for transport. "Randomly selected" means packagings for testing are periodically taken after final assembly or obtained by entering or adding to a standard production order so that an adequate number of representative samples are obtained.

Sample Identification – Label each drum in the sample batch with "Test Control Label" prior to performing UN testing.

Overflow Capacity – Determine the overflow capacity with the metered water source (LAB EQUIPMENT TL007, Appendix A) or by the gravimetric method. (see Appendix C)

Tare Weight – Determine tare weight by weighing empty sample drums on the floor scale. (LAB EQIPMENT TL015, Appendix A)

Drop Test

Test Designation	Samples for Testing -Labels-
Drop Test-First Drop – Diagonal on Bottom chime & welded longitudinal seam	L1 L2 L3
Drop Test- Second Drop – *Determined to be "Weakest Part Not Tested by 1st Drop" – as per the regulations*	L4 L5 L6
Leakproofness Test	L7 L8 L9
Hydrostatic Test	L10 L11 L12
Stack Test	L13 L14 L15

Drop Test §178.603	
Overview	Drums are filled with water to 98 percent of overflow capacity and are dropped onto a solid surface at varying attitudes. Following the drop, the drums must be vented to equalize the internal and external pressure and determine leakage.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	No leakage of the filling substance from the drum other than an initial spurt or spray on impact.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur..
Target	Rigid, non resilient, flat and horizontal surface e.g 3/4" thick steel plate over reinforced concrete mass
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Substance	Water
Fill Level	98% of maximum capacity Fill Level >=(Maximum Overflow Capacity x .98)
Drop Height	As determined by prior experimentation or by customer specification
Sample Size	6 drums L1, L2, L3, L4, L5, L6
Closures	Tighten fittings to torque according to closing instructions
Conditioning	Ambient
Test Duration	Sufficient to reach equilibrium between internal and external pressure

First Drop - Diagonal on bottom chime & welded longitudinal seam **(Samples L1, L2, L3)**

5.1 **Preparation** – Fill **Sample L1** to98% of Overflow Capacity. Insert plugs and tighten to specified torque.

5.2 **Center of Gravity** – Attach adjustable lifting clamp to sample drum and determine the center of gravity (see figure 5.1).

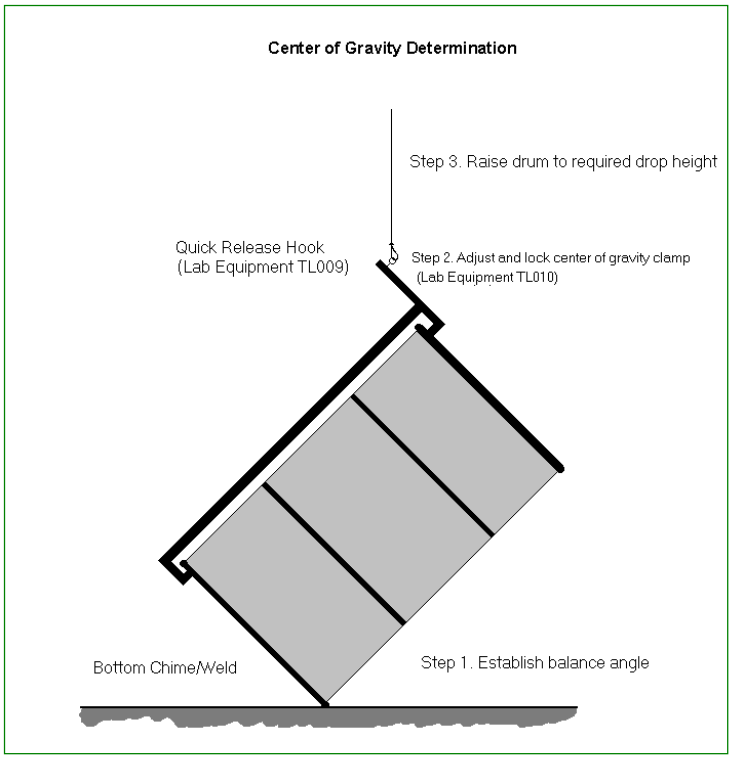


Figure 5.1 – Center of Gravity

5.3 Orient the drum so that the intersection of the welded longitudinal seam and bottom chime (T-zone) are at the point of impact (6 o'clock position).

5.4 **Chime Drop Test–** Lift sample drum to the specified test height. (see figure 5.2). The drop height is measured from the lowest point of the steel drum to the impact surface. Safely stand back and pull the release mechanism allowing the drum to drop onto the solid surface. A small amount of vacuum is typically created inside the drum. Equalize pressure by venting the drum For example drill or punch a small hole (1/4-inch) near the top chime.

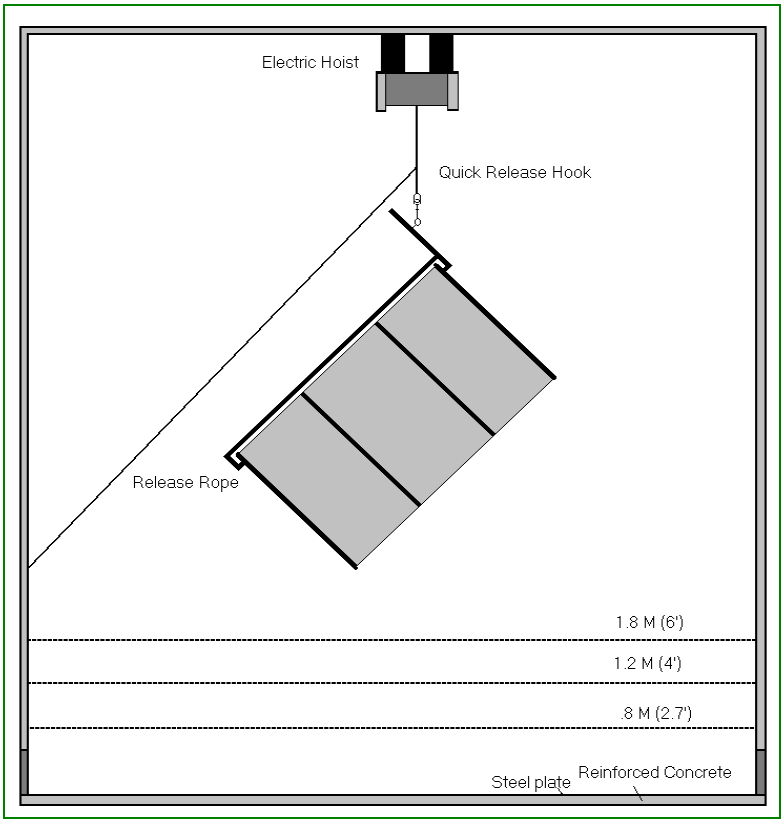


Figure 5.2 – Drop Test (Bottom Chime & Welded Seam)

5.5 **Results**: After venting, visually inspect drum for leaks.

PASS: Record results
FAIL: End this Design test series and determine corrective action

REPEAT 5.1 – 5.5 for Samples L2 - L3.

Second Drop

The second drop series must strike the target on the weakest part not tested by the first drop series.

Samples L4, L5, L6

5.6 **Preparation** – Fill **Sample L4** to 98% of Overflow Capacity. Insert plugs and tighten with required torque

5.7 Orient the drum in order to test the weakest part not tested by the first drop. If using a diagonal drop, attach adjustable lifting clamp to sample drum and determine the center of gravity (see figure 5.1).

5.8 **Chime Center of Gravity** – If conducting a diagonal drop, attach adjustable lifting clamp to sample drum and determine the center of gravity (see figure 5.1).

5.9 **Drop Test**- Lift sample drum to the desired test height as specified. The drop height is measured from the lowest point of the steel drum to the impact surface. Safely stand back and pull the release mechanism allowing the drum to drop onto the solid surface. A small amount of vacuum is typically created inside the drum. Equalize pressure by venting the drum. For example drill or punch a small hole (1/4-inch) near the top chime.

5.10 **Results**: After venting, visually inspect drum for leaks.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

REPEAT steps 5.6 - 5.10 for Samples L5 and L6.

Leakproofness Test

Leakproofness Test § 178.604	
Overview	With closures in place, internal pressure is applied to the drum while submerged under water for a minimum of five minutes.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	No leakage of air from the drum.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur.
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Level	Empty
Test Pressure	**US Standards** Packing Group I 30 kPa (4 PSI) Packing Group II 20 kPa (3 PSI) Packing Group III 20 kPa (3 PSI)
Sample Size	3 drums L7, L8, L9
Closures	Tighten fittings to specified torque. Vented closures must either be replaced by similar non-vented closures or the vent must be sealed.
Conditioning	Ambient
Test Duration	Minimum 5 minutes (not required for production testing)

Leakproofness Test (Samples L7, L8, L9)

5.11 **Preparation** – Insert plugs into **Sample L7** and tighten to the required torque. Use the heavy duty lever tool to install the 3/8" steel Rivet-Nut *(LAB EQUIPMENT TL003)* into the head of the sample drum. Attach the pressure gauge and submerge the drum in the water test tank. (See figure 5.3.)

5.12 **Leakproofness Test** – Apply internal air pressure to sample drum for a minimum of five minutes. Record the start time and stop time.

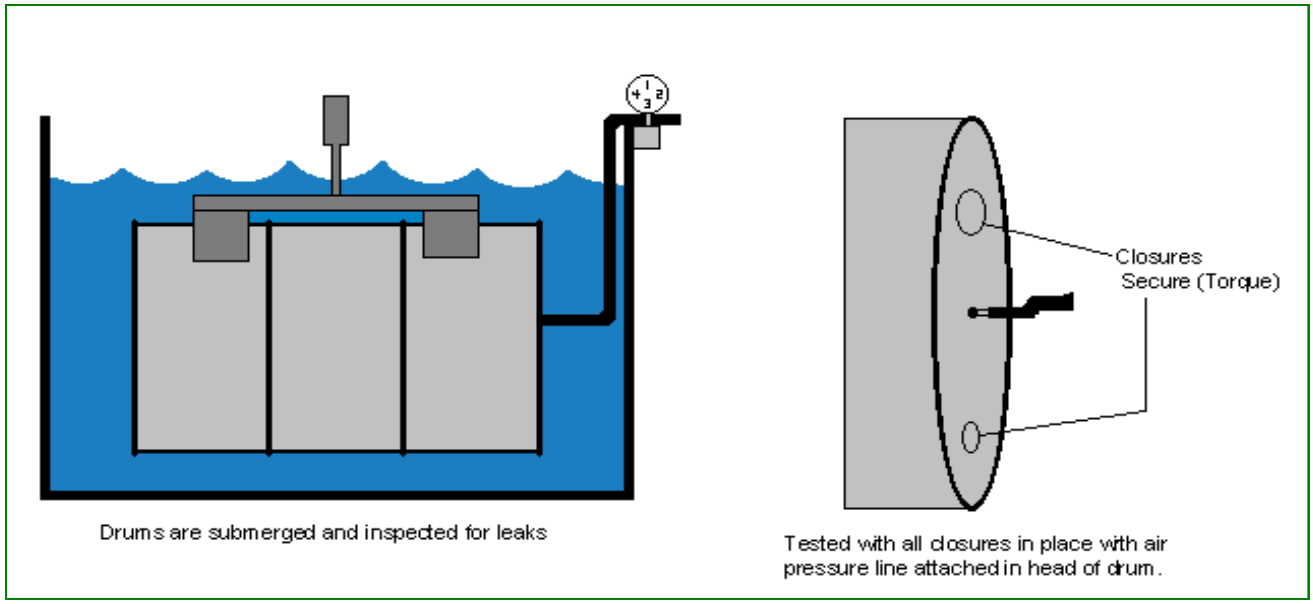


Figure 5.3 – Leakproofness Test

Note: Underwater leak testing is not the only approved method. Alternative Leakproofness Test Methods in Appendix B to 49 CFR Part 178 are allowed.

Leakproofness testing using ultrasonic sensors has been approved as a test method in site specific cases under the U.S. DOT (Competent Authority) process for granting Approvals. These instances have typically required a site visit from authorities to review the specifications and configuration of sensors and related test equipment. In time, the method will be proposed by industry for inclusion in the regulations as a method universally available.

5.13 While pressurized, visually inspect drums for leaks.

PASS: Record results
FAIL: End this Design test series and determine corrective action

REPEAT 5.11 – 5.13 for Samples L8 and L9.

Hydrostatic Test

Hydrostatic Pressure Test § 178.605	
Overview	Drums are filled and pressurized with water to the required pressure for five minutes.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	No leakage of water from the drum or closures.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Level	100% of maximum capacity with water
Test Pressure	As determined by prior experimentation or by customer specifications. Packing Group I must be tested to a minimum test pressure of 250 kPa (36 psi). The kPa for PG II and PG III depends on the lading.
Sample Size	3 drums L10, L11, L12
Closures	Tighten fittings to torque according to the closing instructions Vented closures must either be replaced by similar non-vented closures or the vent must be sealed
Conditioning	Ambient
Test Duration	5 minutes at required pressure

Hydrostatic Pressure Test (Samples L10, L11, L12)

5.14 **Preparation** – Insert plugs into **Sample L10** and tighten with required torque. Using the heavy-duty lever tool, install the 3/8" steel Rivet-Nut into the head of the sample drum. Attach the hydrostatic pressure supply to the Rivet-Nut insert. Make sure the system is completely filled with water.

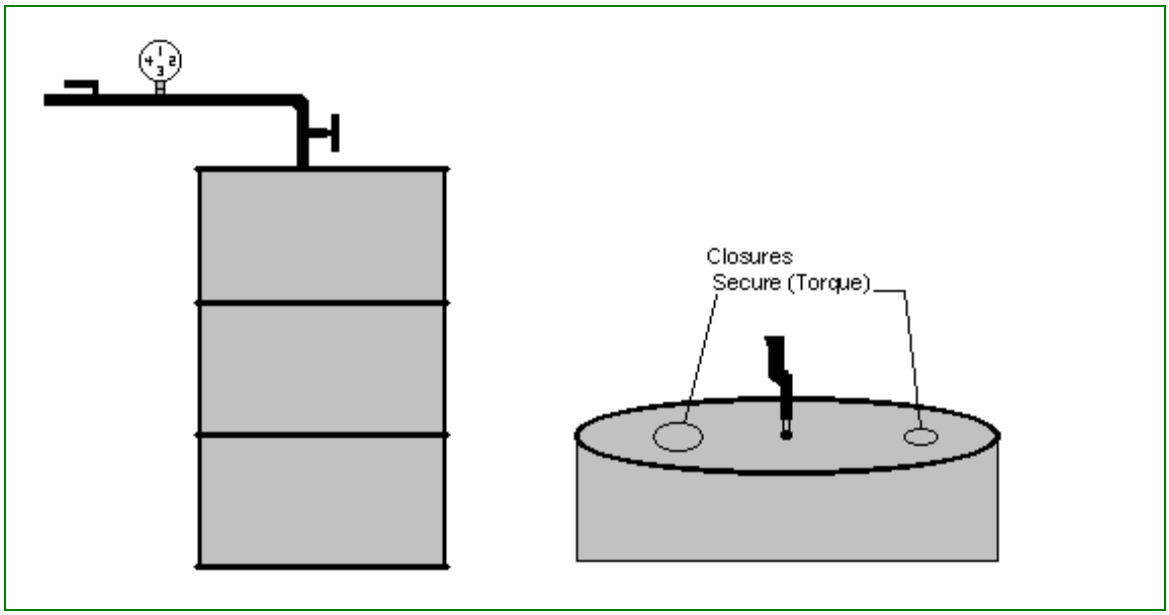


Figure 5.4 – Hydrostatic Pressure Test

5.15 **Hydrostatic Pressure Test** – Completely dry all external surfaces of the sample drum.

5.16 **Test Pressure** – Hydrostatically pressurize the sample drum at a rate of 50 kPa/min to the required pressure and maintain for five minutes. Note: The total time to reach the prescribed pressure should not be less than two minutes and not greater than 5 minutes.

5.17 **Results:** Visually inspect drums for leaks.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

Repeat 5.14 – 5.17 for Samples L11 and L12.

Stacking Test

Stacking Test § 178.606	
Overview	Drums are filled with water to 98% of overflow capacity, Drums must be subjected to a test force evenly applied to the top surface of the drum for 24 hours equal to the total weight of identical packages which might be stacked on it during transport. Minimum stack height is 3 meters.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	Test samples may not leak or indicate any deterioration that could adversely affect transport safety or any distortion liable to reduce its strength or cause instability in stacks of drums.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Level	98% of overflow capacity Fill level >= (Overflow Capacity x .98)
Sample Size	3 drums L13, L14, L15
Closures	Tighten fittings to required torque according to the packaging's closing instructions
Conditioning	Ambient
Test Duration	24 hours
Load Determination	Load = [(118"/h)-1] [w + (s * v * 8.3 * .98)] h = container height s = specific gravity w = maximum weight of one empty container in pounds v = maximum capacity in gallons 8.3= lbs/gal for water

Stacking Test (Samples L13, L14, L15)

5.18 **Preparation** – Fill **Sample L13** to the indicated level. Insert plugs and tighten with required torque.

5.19 **Stack Test** – Apply calculated load for a minimum 24-hour period hour period (see figure 5.6). Record start and stop time

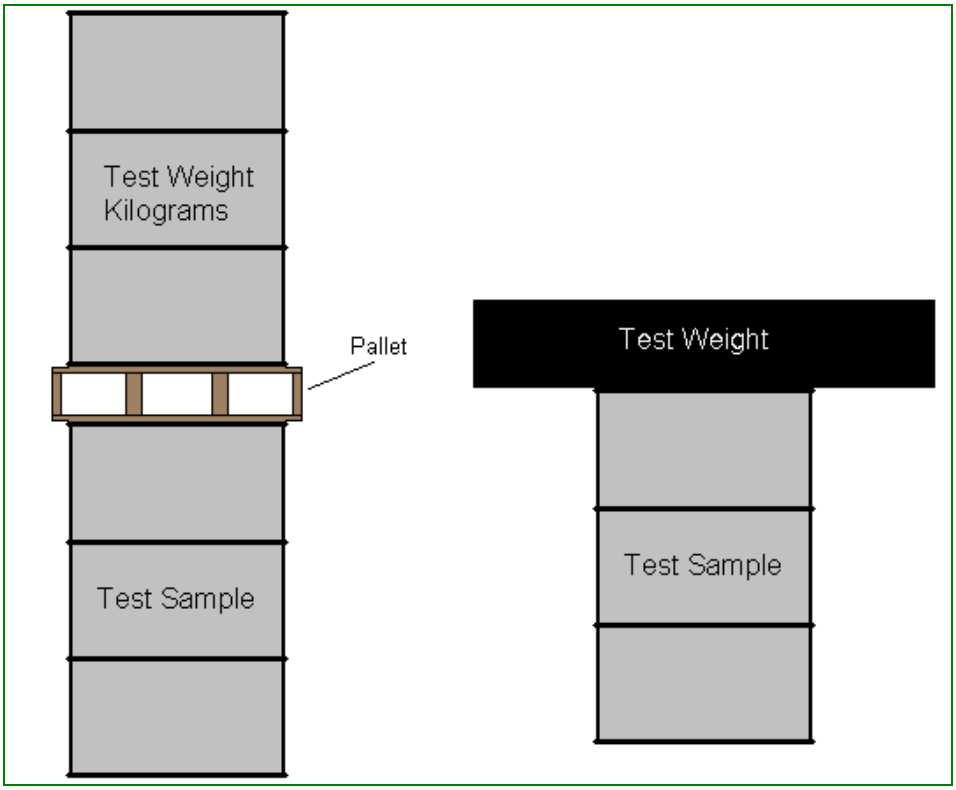


Figure 5.5 – Stack Test

5.20 **Results:** Visually inspect the test samples for leaks or distortion that would adversely affect transportation safety or any distortion likely to reduce the strength or cause instability in stacks of packages.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

REPEAT 5.18 – 5.20 for Samples L14 - L15.

VI. 1A2 Open-Head Steel Drum Testing

1A2 for Liquids

Sample Selection – Randomly select 20 packagings that are representative of those produced as for transport. "Randomly selected" means packagings for testing are periodically taken after final assembly or obtained by entering or adding to a standard production order so that an adequate number of representative samples are obtained.

Sample Identification – Label each drum in the sample batch with "Test Control Label" prior to performing UN testing.

Overflow Capacity – Determine the maximum capacity with the water source *(LAB EQUIPMENT TL007 Appendix A)* or by the gravimetric method (Appendix C).

Tare Weight – Determine the tare weight by weighing empty sample drums on the floor scale *(LAB EQUIPMENT TL016).*

Test Designation	Samples for Testing -Labels-
Drop Test-First Drop – Diagonal on Bottom chime & welded longitudinal seam	H1 H2 H3
Drop Test- Second Drop – *Determined to be "Weakest Part Not Tested by 1st Drop" – as per the regulations*	H4 H5 H6
Leakproofness Test	H7 H8 H9
Hydrostatic Test	H10 H11 H12
Stack Test	H13 H14 H15

Drop Test

Drop Test § 178.603	
Overview	Drums are filled with water to 98 percent of overflow capacity and are dropped onto a solid surface at varying attitudes. Following the drop, the drums must be vented to equalize the internal and external pressure and determine leakage.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	No Leakage of the filling substance from drum other than an initial spurt or spray on impact.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur..
Target	Rigid, non resilient, flat and horizontal surface e.g 3/4" thick steel plate over reinforced concrete mass
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Substance	Water
Fill Level	98% of overflow capacity Fill level >= (Maximum Capacity x .98)
Drop Height	As determined by 49 CFR 178.603 or by customer specification.
Sample Size	6 drums H1, H2, H3, H4, H5, H6
Closures	Attach closure ring with gasket and tighten. Tighten fittings to torque listed in Appendix B or in the packaging's closing instructions.
Conditioning	Ambient

Drop Test – First drop

Diagonal on Bottom Chime & Welded Longitudinal Seam

Samples H1, H2, H3

6.1 **Preparation** – Fill **Sample H1** to 98% of overflow capacity. Attach closure ring with gasket and tighten. Insert plugs and tighten to specified torque.

6.2 **Center of Gravity** – Attach adjustable lifting clamp to sample drum and determine the center of gravity (see figure 6.1

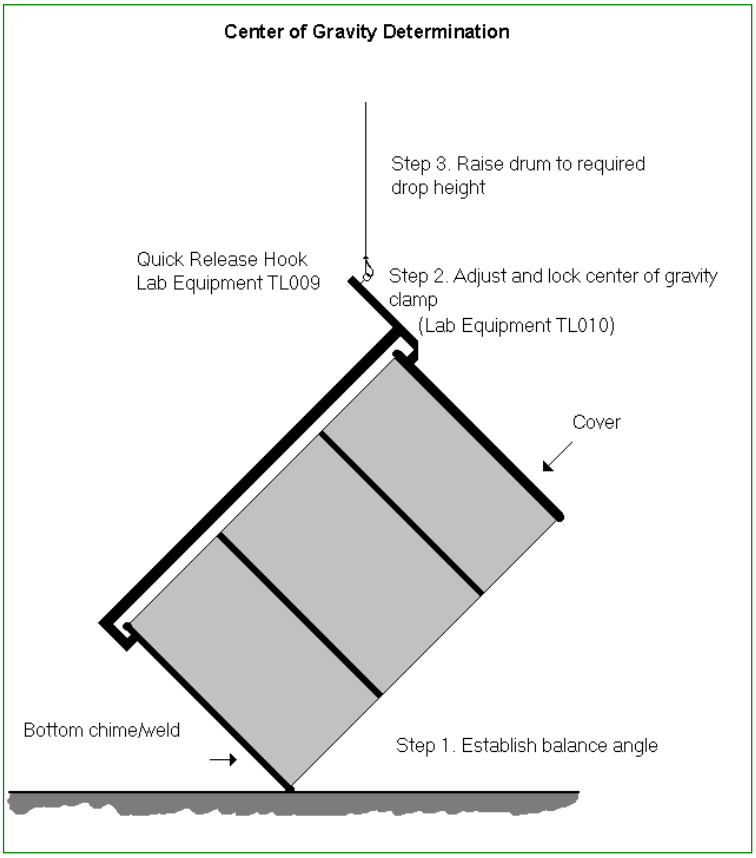


Figure 6.1 – Center of Gravity

6.3 Orient the drum so that the intersection of the welded longitudinal seam and bottom chime (T- zone) are at the point of impact (6 o'clock).

6.4 **Chime Drop Test** – Lift sample drum to the specified test height (see figure 6.2). The drop height is measured from the lowest point of the steel drum to the impact surface. Safely stand back and pull the release mechanism allowing the drum to drop onto the solid surface. A small amount of vacuum is typically created inside the drum. Equalize pressure by venting the drum For example drill or punch a small hole (1/4-inch) near the top chime.

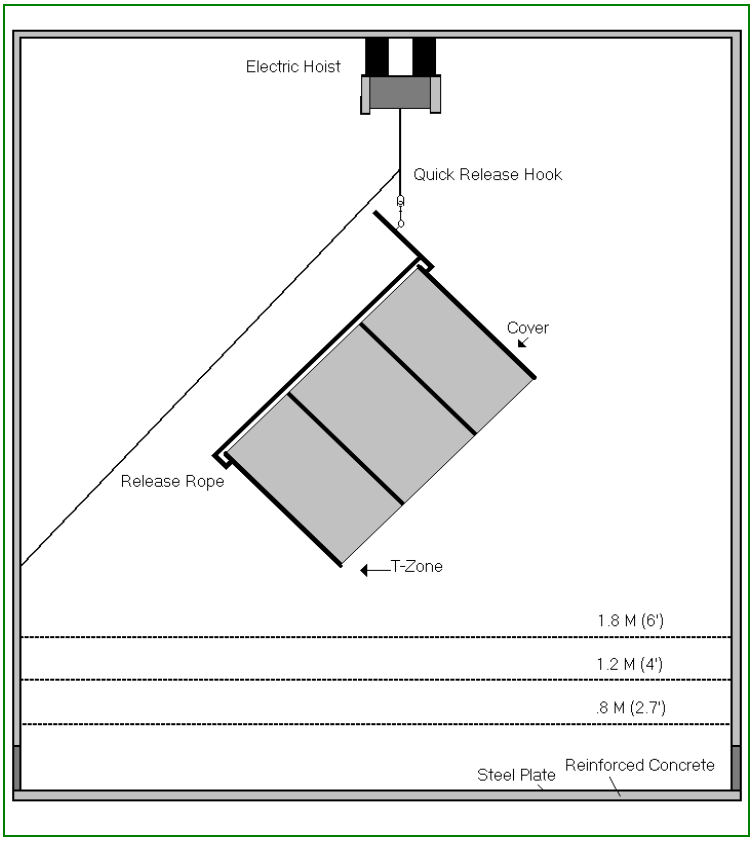


Figure 6.2 – Drop Test (Bottom Chime and Welded seam)

6.5 **Results:** After venting, visually inspect drum for leaks.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

REPEAT 6.1 – 6.5 for Samples H2 and H3.

Second Drop

The second drop series must strike the target on the weakest part not tested by the first drop series.

Samples H4, H5, H6

6.6 **Preparation** – Fill **Sample H4** to 98% of overflow capacityl. Attach the closure ring with gasket and tighten. Insert plugs and tighten with required torque.

6.7 Orient the drum in order to test the weakest part note tested by the first drop. If using a diagonal drop, attach adjustable lifting clamp to sample drum and determine the center of gravity (see figure 6.1)

6.8 **Center of Gravity** – Attach adjustable lifting clamp *(LAB EQUIPMENT TL006 & TL009)* to sample drum and determine the center of gravity (see figure6.1).

6.9 **Drop Test**- Lift sample drum to the desired test height as specified. The drop height is measured from the lowest point of the steel drum to the impact surface. Safely stand back and pull the release mechanism allowing the drum to drop onto the solid surface. A small amount of vacuum is typically created inside the drum. Equalize pressure by venting the drum. For example drill or punch a small hole (1/4-inch) near the top chime.

6.10 **Results:** After venting, visually inspect drum for leaks.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

Repeat 6.6 – 6.10 for Sample H5-H6.

Leakproofness Test

Leakproofness Test § 178.604	
Overview	With closures in place, internal pressure is applied to the drum while submerged under water for a minimum of five minutes.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	No leakage of air from the drum.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Level	Empty
Test Pressure	**US Standards** Packing Group I 30 kPa (4 PSI) Packing Group II 20 kPa (3 PSI) Packing Group III 20 kPa (3 PSI)
Sample Size	3 drums H7, H8, H9
Closures	Attach closure ring with gasket and tighten Tighten fittings to specified torque. Vented closures must either be replaced by similar non-vented closures or the vent must be sealed
Conditioning	Ambient
Test Duration	Minimum 5 minutes (not required for production testing)

Leakproofness Test **Samples H7, H8, H9**

6.11 **Preparation** – Attach closure ring with gasket and tighten. Insert plugs into **Sample H7** and tighten with required torque. Use the heavy-duty lever tool to install the 3/8" steel Rivet-Nut into the head of the sample drum. Attach the pressure gauge and submerge the drum in the water test tank (see figure 6.3).

5.12 **Leakproofness Test** – Apply internal air pressure to sample drum for a minimum of five minutes. Record the start time and stop time.

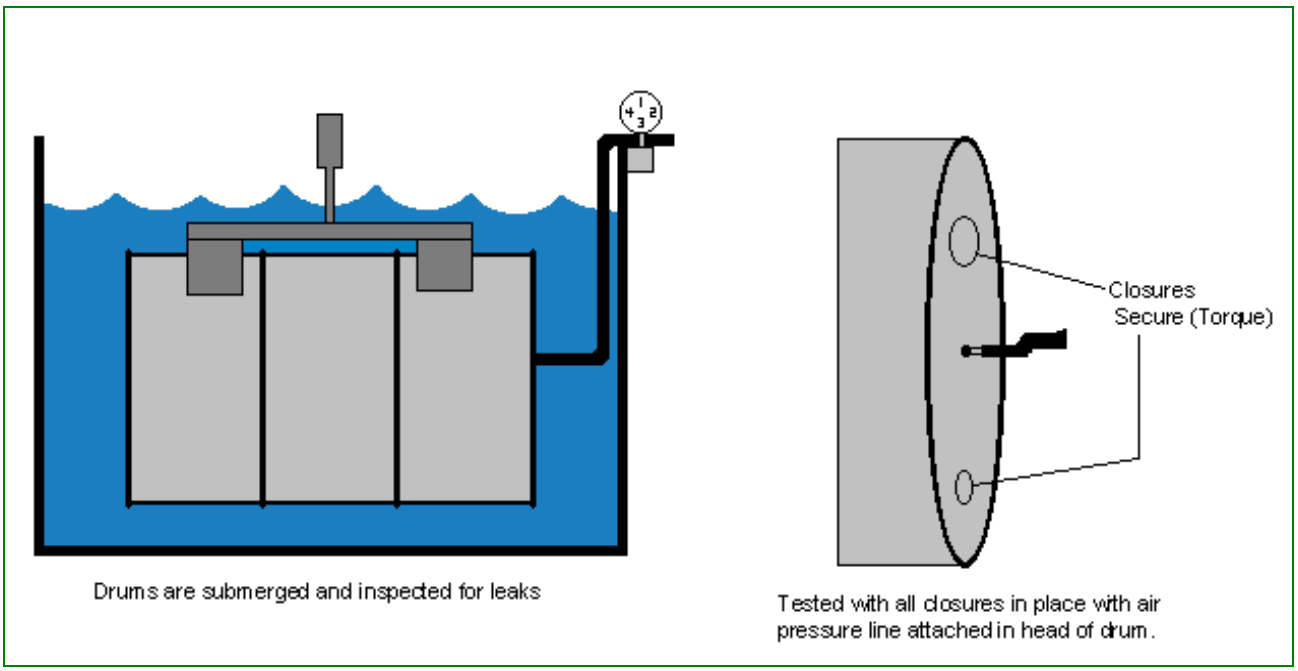


Figure 6.3 – Leakproofness Test

Note: Underwater leak testing is not the only approved method. Alternative Leakproofness Test Methods in Appendix B to 49 CFR Part 178 are allowed.

Leakproofness testing using ultrasonic sensors has been approved as a test method in site specific cases under the U.S. DOT (Competent Authority) process for granting Approvals. These instances have typically required a site visit from authorities to review the specifications and configuration of sensors and related test equipment. In time, the method will be proposed by industry for inclusion in the regulations as a method universally available.

6.13 **Result:** While pressurized, visually inspect drums for leaks.

PASS: Record results.
Fail: End this Design test series and determine corrective action

REPEAT steps 6.11 – 6.13 for Samples H8 and H9.

Hydrostatic Pressure Test

Hydrostatic Pressure Test § 178.605	
Overview	Drums are filled and pressurized with water to the required pressure for five minutes.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	No leakage of air or water from the drum or closures.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Level	100% of maximum capacity with water
Test Pressure	As determined by prior experimentation or by customer specifications. Packing Group I must be tested to a minimum test pressure of 250 kPa (36 PSI). kPa for PG II and III depends on lading
Sample Size	3 drums H10, H11, H12
Closures	Attach closure ring with gasket and tighten. Tighten fittings to specified torque. Vented closures must either be replaced by similar non-vented closures or the vent must be sealed.
Conditioning	Ambient
Test Duration	5 minutes at required pressure

Hydrostatic Pressure Test (Samples H10, H11, H12)

6.14 **Preparation** – Insert plugs into **Sample H10** and tighten with required torque. . Using the heavy-duty lever tool, install the 3/8" steel Rivet-Nut into the head of the sample drum. Attach the hydrostatic pressure supply to the Rivet-Nut insert. Make sure the system is completely filled with water (see figure 6.4)

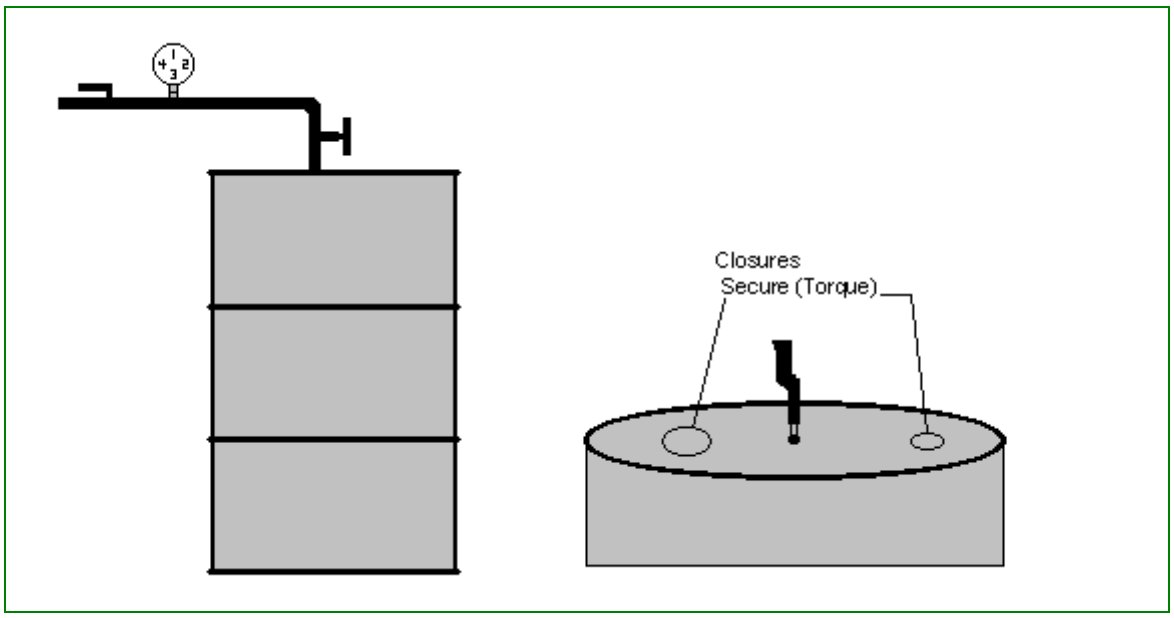


Figure 6.4 – Hydrostatic Pressure Test

6.15 **Hydrostatic Pressure Test** – Completely dry all external surfaces of the sample drum.

6.16 **Test Pressure** – Hydrostatically pressurize the sample drum at a rate of 50 kPa/min to the required pressure and maintain for five minutes.

Note: The total time to reach the prescribed pressure should not be less than two minutes and not greater than 5 minutes.

6.17 **Results:** Visually inspect drums for leaks.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

Repeat 6.14 – 6.17 for Samples H11 and H12.

Stacking Test

Stacking Test	**§ 178.606**
Overview	Drums are filled with water to 98% of overflow capacity, Drums must be subjected to a test force evenly applied to the top surface of the drum for 24 hours equal to the total weight of identical packages which might be stacked on it during transport. Minimum stack height is 3 meters.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	Test samples may not leak or indicate any deterioration that could adversely affect transport safety or any distortion liable to reduce its strength or cause instability in stacks of drums.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Level	Not less than 98% of overflow capacity Fill level >= (Overflow Capacity x .98)
Sample Size	3 drums H13, H14, H15
Closures	Attach closure ring with gasket and tighten Tighten fittings to required torque according to the packaging's closing instructions
Conditioning	Ambient
Test Duration	Minimum 24 hours
Load Determination	Load = [(118"/h)-1] [w + (s * v * 8.3 * .98)] h = container height s = specific gravity w = maximum weight of one empty container in ponds v = maximum capacity in gallons 8.3= lbs/gal for water

Stacking Test Samples H13, H14, H15

6.18 **Preparation** – Fill **Sample H13** to the indicated level. Attach closure ring and tighten. Insert plugs and tighten with specified torque.

6.19 **Stacking Test** – Apply calculated load for a minimum of 24 hour period (see figure 6.5). Record start and stop time.

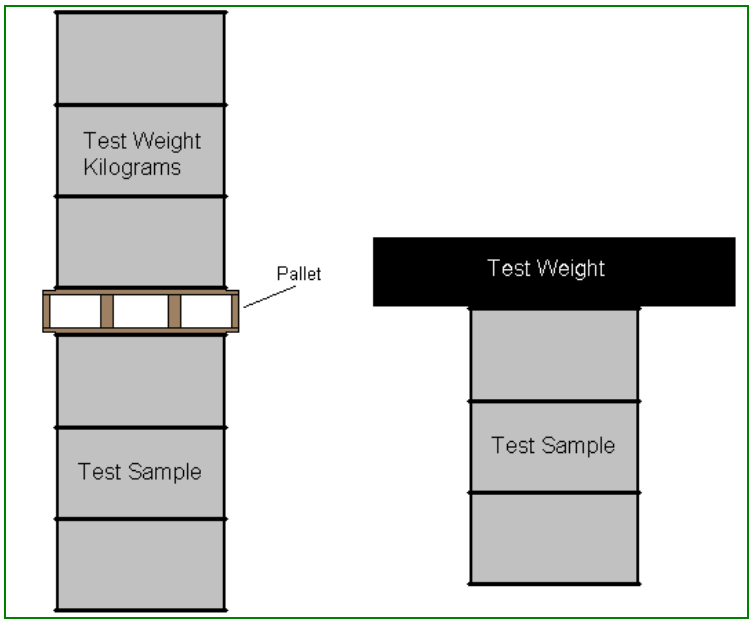


Figure 6.5 – Stacking Test

5.20 **Results:** Visually inspect the test samples for leaks or distortion that would adversely affect transportation safety or any distortion likely to reduce the strength or cause instability in the stacks of packagings.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

REPEAT 5.18 – 5.20 for Samples H14 - H15

VII. 1A2 Open-Head Steel Drum Testing

1A2 for Solids

Sample Selection – Randomly select 12 packagings that are representative of those produced as for transport. “Randomly selected” means packagings for testing are periodically taken after final assembly or obtained by entering or adding to a standard production order so that an adequate number of representative samples are obtained.

Sample Identification – Label each drum in the sample batch, Test Control Label, prior to performing UN testing.

Overflow Capacity – Determine the overflow capacity with the metered water source (LAB EQUIPMENT TL007, Appendix A) or by the gravimetric method. (Appendix C)

Tare Weight – Determine tare weight by weighing empty sample drums on the floor scale. (LAB EQUIPMENT TL015)

Test Designation	Samples for Testing – Labels
Drop Test – First Drop Diagonal on Bottom Chime & Welded Longitudinal Seam	S1 S2 S3
Drop Test – Second drop on the weakest part not tested by the first drop as per the regulations	S4 S5 S6
Stack Test	S7 S8 S9

Drop Test

Drop Test § 178.603	
Overview	Drums are filled with material of the same specific gravity of the material to be carried and its other physical properties which may influence the test. Drums should be filled to 95 percent of overflow capacity and dropped from the height determined by the Packing Group designation at various attitudes.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	No Leakage of the filling substance from drum other than an initial spurt or spray of the solid fill material on impact.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur
Target	Rigid, non resilient, flat and horizontal surface e.g 3/4" thick steel plate over reinforced concrete mass
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Substance	Material used must be of the same or higher specific gravity as the material to be carried, and its other physical properties (grain, size, viscosity) which might influence the results of the tests. It is permissible to use additives such as bags of lead shot to achieve the total package mass so long as they do not affect the test results.
Fill Level	Not less than 95% of Maximum capacity Fill level >= (Maximum Capacity x .95)
Drop Height	As determined by 49 CFR 178.603
Sample Size	6 drums S1, S2, S3, S4, S5, S6
Closures	Attach closure ring with gasket and tighten. Tighten fittings to specified torque.
Conditioning	Ambient

First Drop

Diagonal on Bottom Chime & Welded Longitudinal Seam

Samples S1, S2, S3

7.1 **Preparation** – Fill **Sample S1** to the indicated level. Attach closure ring with gasket and tighten. Insert plugs and tighten with required torque.

7.2 **Center of Gravity** – Attach adjustable lifting clamp to sample drum and determine the center of gravity (see figure 7.1 Lock the eye hook bolt of the adjustable drum clamp at the center of gravity.

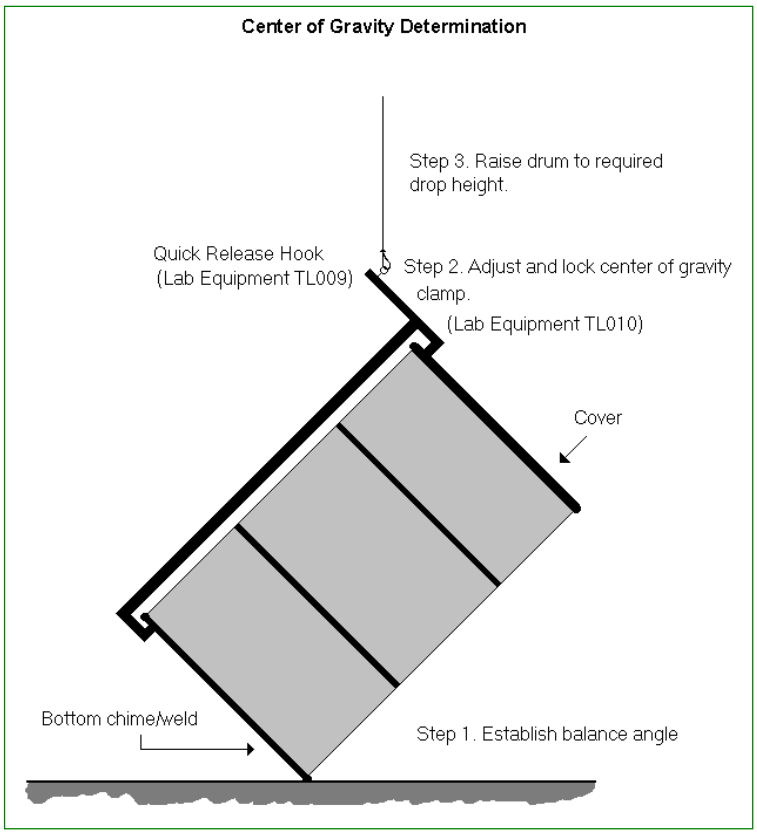


Figure 7.1 – Center of Gravity

7.3 Orient the drum so that the intersection of the welded longitudinal seam and bottom chime (T-zone) are at the point of impact (6 o'clock position).

7.4 **Chime Drop Test** – Lift sample drum to the desired test height as indicated. The drop height is measured from the lowest point of the steel drum to the impact surface. Safely stand back and pull the release mechanism allowing the drum to drop onto the solid surface.

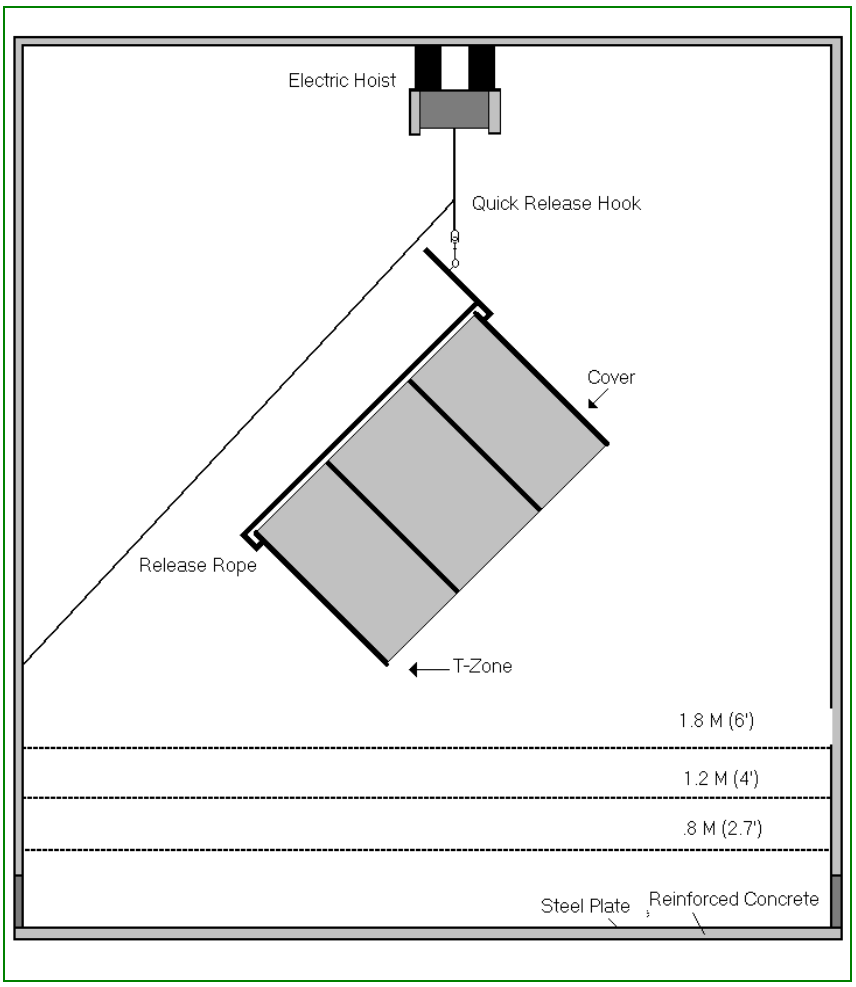


Figure 7.2 – 1st Drop Test (Bottom Chime & Weld Seam)

7.5 **Results:** Visually inspect the drum to see whether the entire contents are contained (e.g., by an inner bag) and/or any discharge from a closure is slight and ceases immediately after impact.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

Repeat 7.1 – 7.5 for Samples S2 - S3.

Second Drop

The second drop series must strike the target on the weakest part not tested by the first drop series.

Samples S4, S5, S6

7.6 **Preparation** – Fill **Sample S4** to 95% of overflow capacity.. Attach the closure ring with gasket and tighten. Insert plugs and tighten with required torque.

7.7 Orient the drum in order to test the weakest part note tested by the first drop. If using a diagonal drop, attach adjustable lifting clamp to sample drum and determine the center of gravity (see figure 7.1).

7.8 **Center of Gravity** – Attach adjustable lifting clamp to sample drum and determine the center of gravity (see figure 6.1). Lock the eye hook bolt of the adjustable drum at the center of gravity.

7.9 **Drop Test -** Lift sample drum to the desired test height as specified. The drop height is measured from the lowest point of the steel drum to the impact surface. Safely stand back and pull the release mechanism allowing the drum to drop onto the solid surface. A small amount of vacuum is typically created inside the drum. Equalize pressure by venting the drum. For example drill or punch a small hole (1/4-inch) near the top chime.

7.10 **Results:** Visually inspect drum to see whether the entire contents are contained (e.g., by an inner bag) and/or any discharge a closure is slight and ceases immediately after impact.

PASS: Record results.
FAIL: End this design test series and determine corrective action

Repeat 7.7 – 7.10 for Sample S2-S3.

Stacking Test

Stacking Test § 178.606	
Overview	Filled as for shipment, drums must be subjected to a test force evenly applied to the top surface of the drum for 24 hours equal to the total weight of identical packages which might be stacked on it during transport. Minimum stack height is 3 meters.
Design Qualification	Initial Test
Periodic Retest	Every 12 months
Criteria for Passing	Test samples may not leak or indicate any deterioration that could adversely affect transport safety or any distortion liable to reduce its strength or cause instability in stacks of drums.
Failures	Note the failure and end the design test series. An analysis to determine corrective action should occur
Equipment	See UN TESTING LAB EQUIPMENT – Appendix A
Fill Level	Not less than 95% of overflow capacity Fill level >= (Overflow Capacity x .95)
Sample Size	3 drums S7, S8, S9
Closures	Attach closure ring with gasket and tighten. Tighten fittings to specified torque.
Conditioning	Ambient
Test Duration	Minimum 24 hours
Load Determination	Load = [(118”/h)-1] [w + (s * v * 8.3 * .95)] h = container height s = specific gravity w = maximum weight of one empty container in pounds v = maximum capacity in gallons

Stacking Test Samples S7, S8, S9

7.11 **Preparation** – Fill **Sample S7** to95% of overflow capacityl. Attach closure ring and tighten in accordance with fitting manufacturer's instructions. Insert plugs and tighten with required torque as specified in Appendix B or in the closing instructions.

7.12 **Stack Test** – Apply calculated load for a 24-hour period (see figure 6.5). Record start and stop time.

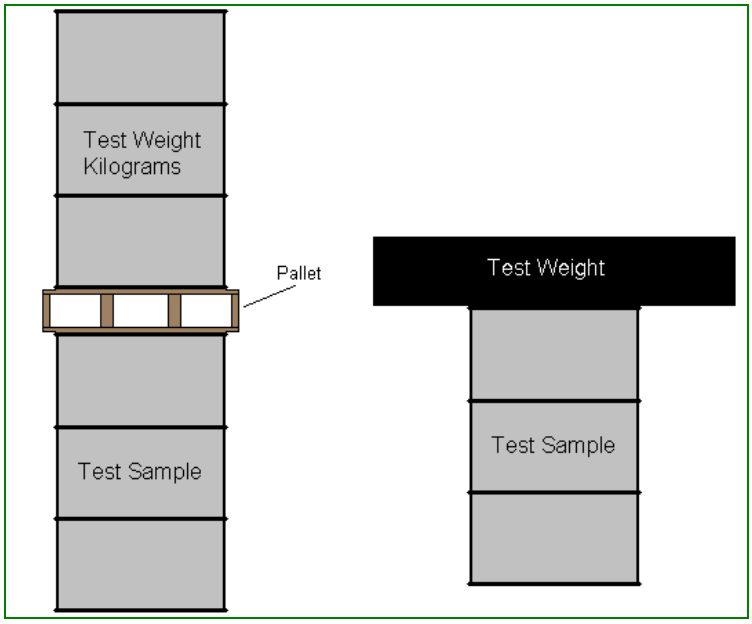


Figure 7.3 – Stack Test

7.13 **Results:** Visually inspect the test samples for leaks or distortion exceeding one inch.

PASS: Record results.
FAIL: End this Design test series and determine corrective action

Repeat 7.11 – 7.13 for Samples S8 and S9.

VIII. Appendices A – C

The equipment listed in Appendix A is illustrative of what may be needed to perform the required UN performance tests. Similar equipment is available from various manufacturers and can be used provided the calibration schedule is maintained.

Appendix A **UN Lab Testing Equipment**		
ID #	**Description**	**Recommended Calibration (see note below)**
TL 001	1/2" torque wrench, 0-150 ft. lbs./0-200 newton meters,	Annual
	Thread setter,	N/A
TL 003	3/8” – 16 thread size Klik rivet nuts,	N/A
TL 004	Water submersion tank w/ hydraulic ram (300 gallon capacity)	N/A
TL 005	3/16” fill attachment with gauge, 0-60 psi,	Annual
TL 006	Adjustable center of gravity clamp	N/A
TL 007	Water quantity flow meter.	Annual
TL 008	3/16” air pressure fill attachment	N/A
TL 009	Drop test lifting rack with electric crane (1,000 pound capacity)	N/A
TL 010	Quick release drop test clamp	N/A
TL 011	Hook chain clamp	N/A
TL 012	3/8” X 1/8” O-ring,	N/A
TL 013	1/2" X 1/8” O-ring,	N/A
TL 015	Stack test weight	Annual
TL 016	Floor scale	Annual
TL 017	Stop watch	N/A
TL 018	Thermometer	N/A
TL 019	Hydrostatic test pressure gauge	Annual
TL 020	Leakproofness test pressure gauge	Annual
TL 021	Drop height measurement stick	Annual

Note: Calibration cycles should be determined by each lab. The table above provides general recommendations. Each self –certifier is required to have an approved quality control system.

Appendix B

UN Test Levels – Drop Test

SG = Specific Gravity of lading

Packing Group IIII (Z)			Packing Group II (Y)			Packing Group I (X)		
SG	Meters	Inches	SG	Meters	Inches	SG	Meters	Inches
1.20	0.80	31.65	1.20	1.20	47.24	1.20	1.80	70.87
1.30	0.80	34.29	1.30	1.30	51.18	1.30	1.95	76.77
1.40	0.90	36.96	1.40	1.40	55.12	1.40	2.10	82.68
1.50	1.01	39.57	1.50	1.50	59.06	1.50	2.25	88.58
1.60	1.07	42.20	1.60	1.60	62.99	1.60	2.40	94.49
1.70	1.14	44.84	1.70	1.70	66.93	1.70	2.55	100.39
1.80	1.21	47.48	1.80	1.80	70.87	1.80	2.70	106.30
1.90	1.27	50.12	1.90	1.90	74.80	1.90	2.85	112.20
2.00	1.34	52.76	2.00	2.00	78.74	2.00	3.00	118.11
2.10	1.41	55.39	2.10	2.10	82.68	2.10	3.15	124.02
2.20	1.47	58.03	2.20	2.20	86.61	2.20	3.30	129.92
2.30	1.54	60.67	2.30	2.30	90.55	2.30	3.45	135.83
2.40	1.61	63.31	2.40	2.40	94.49	2.40	3.60	141.73
2.50	1.68	65.94	2.50	2.50	98.43	2.50	3.75	147.64
2.60	1.74	68.58	2.60	2.60	102.36	2.60	3.90	153.54
2.70	1.81	71.22	2.70	2.70	106.30	2.70	4.05	159.45
2.80	1.88	73.86	2.80	2.80	110.24	2.80	4.20	165.35
2.90	1.94	76.50	2.90	2.90	114.17	2.90	4.35	171.26
3.00	2.01	79.13	3.00	3.00	118.11	3.00	4.50	177.17

Use this table and/or formulas below to determine drop heights

Packing Group I (Hazard Class X): **SG x 1.5 m**
Packing Group II (Hazard Class Y): **SG x 1.0 m**
Packing Group III (Hazard Class Z): **SG x 0.67 m**

Appendix C

Gravimetric Procedure for Determining Capacity

Table 1 – Water Densities

Degrees F			Degrees C				Density*		Lbs./Gal
1 Gal. @	40	or	4.44	=	8.345	X	.99999	=	8.345
1 Gal. @	45	or	7.22	=	8.345	X	.99992	=	8.344
1 Gal. @	50	or	10.00	=	8.345	X	.99973	=	8.343
1 Gal. @	55	or	12.78	=	8.345	X	.99943	=	8.340
1 Gal. @	60	or	15.56	=	8.345	X	.99904	=	8.337
1 Gal. @	65	or	18.33	=	8.345	X	.99857	=	8.333
1 Gal. @	70	or	21.11	=	8.345	X	.99800	=	8.328
1 Gal. @	75	or	23.89	=	8.345	X	.99735	=	8.323
1 Gal. @	80	or	26.67	=	8.345	X	.99663	=	8.317

*Relative density from "Handbook of Chemistry & Physics" from Smithsonian Tables compiled by various authorities

(a) Weigh the empty container
(b) Completely fill the container with water and weigh the filled container
(c) Measure the temperature of the water
(d) Determine the net weight by formula:
Filled Weight – Empty Weight = Weight of Water

Then, using the proper density from Table 1, the capacity is determined by using the following formula:

$$\text{Capacity in Gallons} = \frac{\text{Weight of water in lbs. at observed temperature}}{\text{Weight of water in lbs./gal. at observed temperature}}$$

Reference

Metric Conversions

1 kilogram (kg).....	=	2.20	pounds
1 millimeter (mm).....	=	0.039	inches
1 meter (m).....	=	39.00	inches
1 kiloPascal (kPa).....	=	0.145	PSI
1liter.....	=	0.26	gallons

Specific Gravity (Relative Density)

The ratio of the density of a substance to the density of water. The specific gravity of water is 1.0.

Construction Definition

Steel Gauge Old Description	Steel Gauge New Description	Steel Thickness Millimeters
20/18	18/20/18	1.1/.8/1.1 mm
18	18/18/18	1.1/1.1/1.1 mm
18/16/18	16/18/18	1.4/1.1/1.1 mm

Vapor Pressure

The pressure exerted by a vapor that is in equilibrium with its solid or liquid form.

Steel Thickness

The thickness conversions indicated on this chart are nominal for the steel gauge indicated. Actual minimum tolerances for each corresponding millimeter marking are contained in table 4 of the ISO 3574 tolerance chart.

Steel Gauge	Millimeter Marking	Inches
16	1.4 mm	.0533”
18	1.1 mm	.0428”
19	1.0 mm	.0378”
20	0.8 mm	.0324”
22	0.7 mm	.0269”
24	0.5mm	.0209”

Tolerances (Variances) for Nominal Steel Drum Marks (mm)

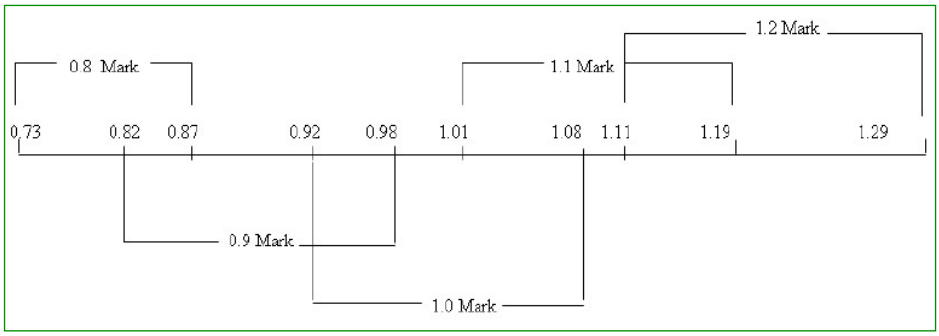


Table of Conversion Factors for SI Units

Measurement	SI to U.S. standard	U.S. standard to SI
Length	1 cm=0.3937008 in 1 m=3.280840 ft	1 in=2.540000 cm 1 ft=0.3048000 m
Thickness	1 mm=0.03937008 in	1 in=25.40000 mm
Mass (weight)	1 kg=2.204622 lb 1 g=0.03527397 oz	1 lb=0.4535924 kg 1 oz=28.34952 g
Pressure	1 kPa=0.1450377 psi 1 Bar=100 kPa=14.504 psi 1 kPa=7.5 mm Hg	1 psi=6.894757 kPa 1 psi=0.06895 Bar
Volume (liquid)	1 L=0.2641720 gal 1 mL=0.03381402 oz 1 m^3=35.31466 ft^3	1 gal=3.785412 L 1 oz=29.57353 mL 1 ft^3=0.02831685 m^3
Density	1 kg/m^3=0.06242797 lb/ft^3	1 lb/ft^3=16.01846 kg/m^3

Abbreviation for units of measure and abbreviation are:

(SI): millimeter, mm; centimeter, cm; meter, m; gram, g; kilogram, kg; kiloPascal, kPa; liter, L; milliliter, mL; cubic meter, m^3; Terabecquerel, TBq; Gigabecquerel, GBq; millisievert, mSv; Newton, N;

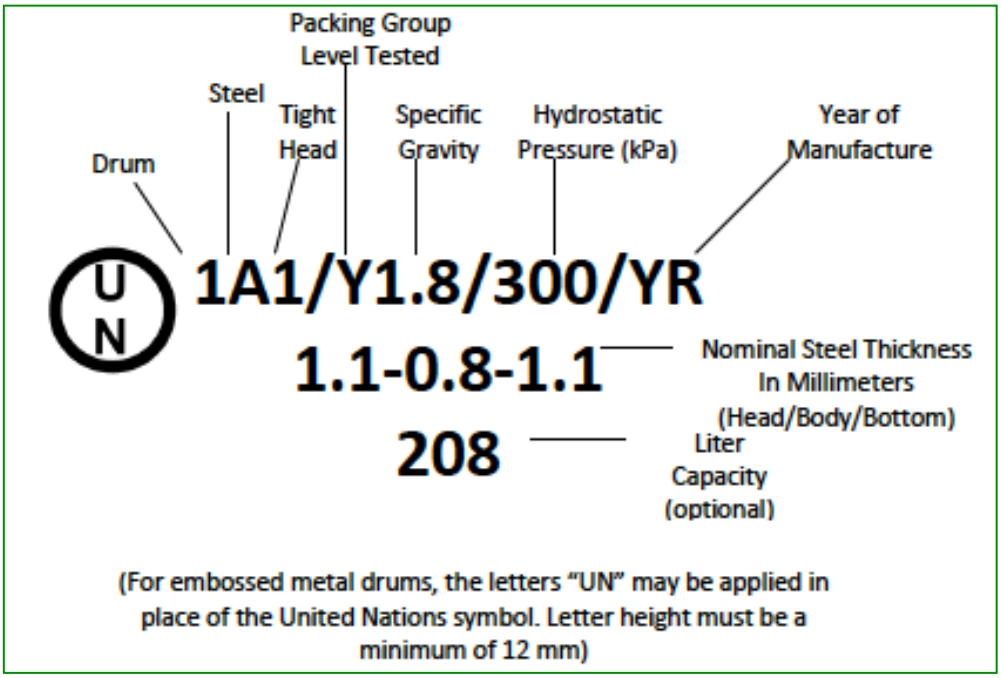
Specific Gravity (Relative Density)
The ratio of the density of a substance to the density of water. The specific gravity of water is 1.0.

Vapor Pressure
The pressure exerted by a vapor that is in equilibrium with its solid or liquid form.

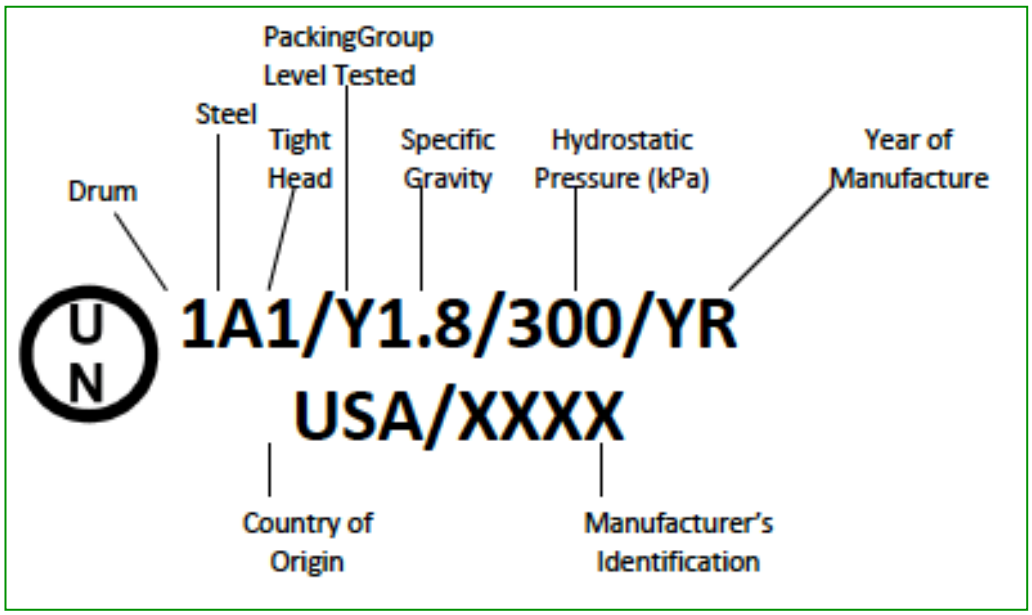
Department of Transportation

Office of Hazardous Materials Safety
Pipeline and Hazardous Materials Safety Administration
U.S. Department of Transportation
1200 New Jersey Avenue, S.W.
Washington, DC 20590-0001
HM Information Center: 800-467-4922
Fax On-Demand: 800-467-4922, X-2
www.phmsa.dot.gov/hazmat

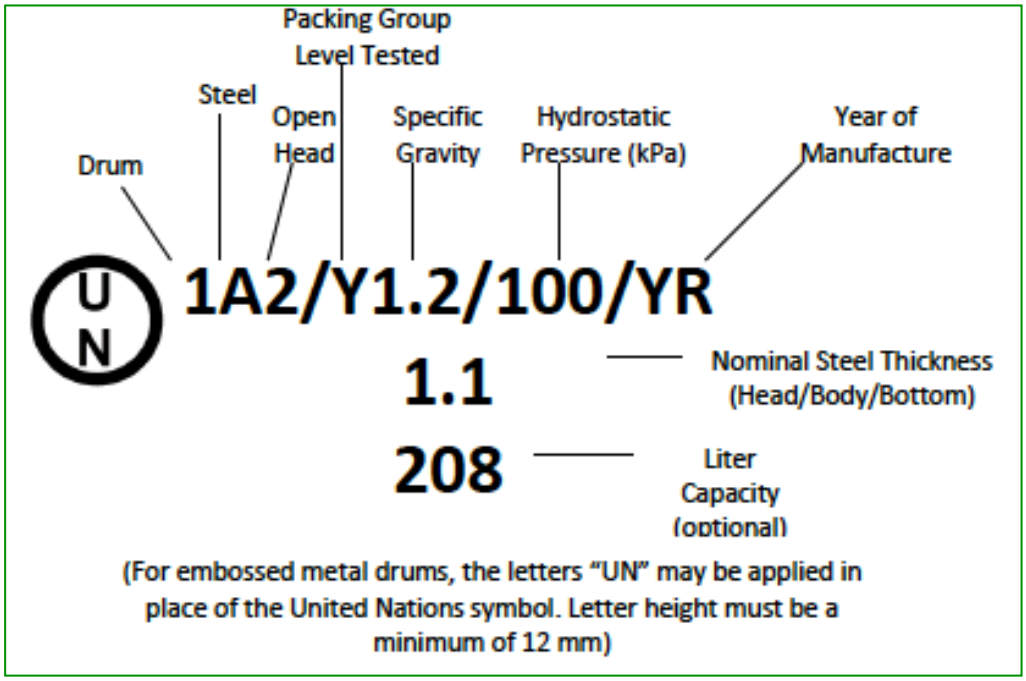
Sample Permanent Markings – Closed Head Bottom Embossment



Sample Durable "Side" Marking – Closed Head (e.g., Adhesive Label)



Sample Permanent Markings – Open head Liquid Bottom Embossment



Sample Permanent Marking – Open head Solid Bottom Embossment