DANGEROUS GOODS PANEL (DGP)

MEETING OF THE WORKING GROUP OF THE WHOLE

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GUIDANCE ON THE PRESSURE DIFFERENTIAL REQUIREMENTS FOR PACKAGES INTENDED TO CONTAIN LIQUIDS IN AIR TRANSPORT

Guidance on the pressure differential requirement for packages intended to contain liquids in air transport

The purpose of this document is to provide guidance relevant to the pressure differential requirements in 173.27(c) of the US Hazardous Materials Regulations (HMR) and Part 4;1.1.6.1 of the International Civil Aviation Organization Technical Instructions on the Safe Transport of Dangerous Goods by Air (ICAO TI).

According to HMR §173.27 and 4;1.1.6 of the ICAO TI each package intended to contain liquids that is offered for transport by air must be capable of meeting a specified pressure differential. HMR; 173.196(a)(6), ICAO packing instructions 620 and 650 require the primary receptacle or secondary packaging used for infectious substances to be capable of withstanding, without leakage, an internal pressure producing a pressure differential of not less than 95 kPa (14 psi). The pressure differential requirement in the HMR and the ICAO TI is consistent. This requirement was specifically developed to address conditions in air transport. It is intended to ensure that hazardous materials packages provide an adequate level of protection from leakage while the package is in transport. The pressure differential requirement is intended to simulate the pressure environments encountered in air transport such as a cabin or cargo compartment depressurization, the pressures experienced in a standard cargo compartment aboard a passenger or cargo aircraft and on feeder aircraft flights involving non-pressurized cargo compartments, and taking into account temperature fluctuations that cause trapped gases and liquids to expand and contract.

The regulations do not specify specific tests for ensuring packages meet the pressure differential requirements. Several methods are commonly used to determine the ability of a package to meet the pressure differential test, including hydrostatic testing, pneumatic testing and vacuum testing. Some of these tests do not fulfil the pressure differential requirement in the case of certain types of packages. In this guidance document, we indicate the test methods considered to be acceptable and those that are not.

Pressure Differential Values

Unless otherwise excepted, packages intended to contain liquids must be capable of withstanding, without leakage, the greater of:

- an internal gauge pressure of at least 75 kPa for liquids in Packing Group III of Class 3 or Division 6.1 (95 kPa for all other liquids); or

- a pressure related to the vapour pressure of the liquid to be transported (see examples provided in Annex 1).

This requirement does not apply, for example, to consumer commodities transported in accordance with Packing Instruction 910.

The vapour pressure of the liquid dangerous goods contributes to the pressure differential experienced by a packaging that undergoes a change in temperature. For example, the vapour pressure of acetone is 24 kPa at 15 °C, and 100 kPa at 50 °C. As

such acetone in a bottle filled at 15 °C would increase the pressure in the bottle by 76 kPa when the temperature in the bottle rises to 50 °C.

In the case of acetone at 15 °C the external air pressure at an altitude of 4572 m (15,000 feet) would be 57kPa. The vapour pressure of the acetone will not exert a positive pressure on the package until the external pressure is below the internal pressure of the package. If the acetone were at 50°C with a resultant vapour pressure of 100 kPa the pressure differential would still only be 68 kPa, the vapour pressure of acetone minus the external air pressure (100 kPa -32 kPa = 68 kPa).

The vapour pressure of the liquid is not the only factor that contributes to the pressure exerted within an inner packaging. Air or other inert gases in the packaging must also be considered.

Pressure differential in the context of a package is the difference between the amount of pressure exerted on the inside of the package and the pressure on the outside.

Differential pressure is expressed mathematically as:

P = Po - Pi , where:
P = differential pressure
Po = pressure in the inside of the packaging
Pi = pressure on the outside of the packaging.

Note: The web site http://www.s-ohe.com/vp_data.html includes vapour pressure charts for many chemicals.

Test Methods

Acceptable test methods include any method that provides the required pressure differential between the inside and outside of a package. Common methods for determining if a package meets the pressure differential requirement include an external vacuum test where the lower pressure is applied on the outside of the package and atmospheric pressure inside of the package. A second variation on this is a vacuum test while the package is restrained under water. In this case, the package is submersed under water and a vacuum is pulled in a sealed chamber above the water. This reduces the pressure above the water and leakage will be seen by bubbles streaming out of the package if the package is unable to withstand the pressure differential. This method is generally not suitable for non rigid packages because the required pressure differential is not attained. Another method is to continually apply pressure from the inside while observing for signs of leakage.

Pressure differential testing is generally performed on representative samples or inner packagings of combination packages that will be used for transporting dangerous goods by aircraft to ensure the packaging is capable of meeting the required differential. The person signing the shipper's declaration is certifying that the inner packaging or an authorized supplementary packaging is can withstand the required pressure differential. RSPA takes packages used to transport hazmat and subjects them to appropriate performance tests. A package represented as meeting the pressure differential requirement but shown not to pass suitable tests performed by RSPA would be considered in violation of the regulations.

A common misconception has been to use a vacuum-tested plastic bag as a supplementary outer packaging to satisfy the pressure differential requirements. RSPA is aware that such bags when actually subjected to pressure differential tests, where the pressure was exerted from within, small bags (10cm x 22.5cm) were typically shown to fail at pressures below 40 kPa. Larger bags (35cm x 66cm) were shown to fail at pressures considerably lower - 13 kPa. The tests also verified that the quantity of air trapped in the bag plays a considerable role in whether the bag passes the test. These bags clearly were not in compliance with the regulations. Furthermore, due to the practical limits of the vacuum test, it should certainly not be considered as a suitable method in the case of high vapour pressure substances (i.e., those substances which should be placed in packages capable of withstanding a pressure differential related to the substance's vapour pressure).

Rigid packaging

A package is considered rigid if it does not volumetrically expand more than 0.5% of its non pressurized volume at ambient temperature when subjected to an internal pressure of one atmosphere (100 kPa/14.7 psi) as specified in ASTM D4991-94.

Several test methods may be used to determine the capability of a rigid packaging to withstand a specified pressure differential. ASTM D-4991-94 (1999) Standard Test Method for Leakage Testing of Empty Rigid Containers by Vacuum Method provides acceptable methods for testing rigid packages. This is a pneumatic test method which is considered the more sensitive method for testing for pressure differential. Other methods use hydrostatic and hydraulic test methods. These are less sensitive and while they may not detect leaks that will be revealed by the pneumatic test, they are considered acceptable particularly because the packages that are being tested are intended to contain liquids. In the case of rigid packages, both a vacuum test or a pressure test using air is considered effective.

A factor for determining the suitability of a vacuum test is the elevation of the laboratory performing the testing. If the laboratory is sited a location of approximately 1,500 feet or above it will be impossible to produce a vacuum induced pressure differential of 95 kPa due to the reduced air pressure at that elevation. Since the vacuum test creates a pressure differential with the ambient air the testing limit is a pressure differential of 101.3 kPa. On this basis, the vacuum test is not considered practicable for demonstrating the ability of a package to withstand pressure differentials greater than 95 kPa - as required in the case of high vapour pressure liquids. For instance, the vacuum test would not be suitable for determining the capability of a package intended for containing any liquid with a vapour pressure greater than 111.4 kPa at 50 ^{0}C or 130 kPa at 55 ^{0}C (e.g. chloroform, acetone and cyclopentane).

Flexible Packaging

A package is considered flexible if it volumetrically expands 0.5% or more when subjected to an internal pressure test of one atmosphere (100 kPa/14.7 psi) as specified in ASTM D4991-94. While several test methods may be used to determine the capability of a rigid packaging to withstand a specified pressure differential, for

flexible packages (e.g. plastic bags or thin walled plastic bottles), it is only possible to obtain a 95 kPa pressure differential on flexible packages using a vacuum test under certain controlled conditions (e.g. when expansion of the flexible packaging is controlled). On this basis, a vacuum test is not considered suitable for meeting the prescribed pressure differential requirement in the HMR and ICAO TI when a pressure differential is not actually achieved due to the expansion of the packaging. When a flexible packaging such as a plastic bag is subjected to a vacuum test, the air inside the bag will cause the flexible packaging to expand until the inside and outside pressures are equivalent. On this basis, a vacuum test is not an acceptable means for verifying that flexible packages are capable of withstanding without leakage a prescribed pressure differential (173.27(c)(2) and Part 3;1.1.6.1 of the ICAO TI) unless it is demonstrated in testing that the flexible packaging is actually subjected to the specified pressure differential. Drawing a vacuum of 95 kPa in most cases will not achieve this requirement.

An acceptable method for testing flexible packages is as follows:

Restrain the packaging under water while applying an internal air pressure; the method of restraint must not affect the results of the test. Inner packagings of combination packagings, inner receptacles of composite packagings and supplementary packagings may be tested without outer packaging. Vented closures must either be replaced by similar non-vented closures or the vent must be sealed. The test must be conducted for a minimum time of ten minutes except for specimens which are single packagings or combination packagings that are constructed of plastic in which case the test must be conducted for 30 minutes (see for instance ASTM 4991). Pressurize the packaging until the specified pressure differential is achieved and can be maintained. Apply the pressure differential continuously and evenly, and keep it constant throughout the test period.

The specified pressure differential to be applied and maintained during the test must be determined in accordance with 49 CFR 173.27(c) (see also ICAO TI 4;1.1.6). Examples are included in Annex 1.

While pressurized, observe the packaging for the signs of leakage for example a continuous stream of recurring bubbles coming from the package. Isolated bubbles caused by trapped air are not considered evidence of leakage. A package passes the pressure differential test if, for each test sample, there is no leakage from the package.

In the case of high vapour pressure substances (liquids with a vapour pressure in excess of 111.4 kPa at 50°C or vapour pressure in excess of 130 kPa at 55°C), 173.27(c) and Part 3;1.1.6.1 require that packages be capable of withstanding pressures higher than 95 kPa to take into account the vapour pressure at these elevated temperatures 50°C and 55°C. Due to the practical limits of the vacuum test, it should certainly not be considered as a suitable method in the case of high vapour pressure substances (i.e., those substances which should be placed in packages capable of withstanding a pressure differential related to the substance's vapour pressure). Furthermore, even in the case of some lower vapour pressures substances (i.e., those substances not subject to the vapour pressure relationships in 3;1.1.6.1 (a), (b) or (c)), flexible packages should not be considered effective on the basis of a vacuum test. For example, using 3;1.1.6.1(b), a packaging used for a substance with a vapour pressure of 50 kPa should be capable of withstanding a pressure differential of 95

kPa. In the case of a 95 kPa vacuum test on flexible packages containing this substance, the pressure differential would be at least 45 kPa (assuming all the air has been evacuated). Based on the pressure tests described above, this pressure is sufficient to cause the above described flexible packages to burst. Ethanol with a vapour pressure of 30 kPa at 50°C is an example of such a substance.

The volume of air retained in the inner packaging at the time it is filled is also a factor to consider in the case of the vacuum test method. Like the air that is trapped in the plastic bag at the time it is sealed, the air left in an inner packaging at the time it is filled will tend to contribute to the bag's failure under a vacuum condition. In the extreme case where an inner packaging is only partially filled, the amount of air in the inner packaging could significantly affect the results of a vacuum test. We do not believe that the amount of air in the bag can be controlled in practice.

On this basis a vacuum test is not considered suitable for determining if a flexible inner packaging is capable of meeting the pressure differential requirements in 173.27(c) or ICAO TI 3;1.1.1.6 unless the specified pressure differential can be measured, maintained and the pressure inside the bag is greater than the pressure outside. This may be achieved under certain conditions by restricting the flexible bag from expanding. In order for a vacuum test to be suitable for a flexible package the pressure determined on the basis of the vapour pressure of the material and the required pressure differential must not exceed the burst pressure of the flexible package. The burst pressure of the flexible package should be determined by testing.

Annex 1

§173.27 and 4;1.1.6 and Example Calculations

Packagings for which retention of liquid is a basic function must be capable of withstanding without leakage an internal pressure which produces a pressure differential of not less than 95 kPa (not less than 75 kPa for liquids in Packing Group III of Class 3 or Division 6.1), or a pressure related to the vapour pressure of the liquid to be conveyed, whichever is the greater. The pressure related to the vapour pressure must be determined as either:

a) the total gauge pressure measured in the packaging (i.e. the vapour pressure of the filling substance and the partial pressure of the air or other inert gases, less 100 kPa) at 55°C, multiplied by a safety factor of 1.5; this total gauge pressure should be determined on the basis of a degree of filling in accordance with 1.1.5 and a filling temperature of 15°C; or

b) 1.75 times the vapour pressure at 50°C less 100 kPa, but with a minimum of 95 kPa.

This is expressed as:

P = (Vp50 × 1.75) − 100 kPa with a minimum of 95 kPa

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where

P = Pressure requirement in kPa (gauge)
Vp50 = Vapour pressure at 50°C; or

c) 1.5 times the vapour pressure at 55°C less 100 kPa, but with a minimum of 95 kPa.

This is expressed as:

P = (Vp55 x 1.5) − 100 kPa with a minimum of 95 kPa

where

P = Pressure requirement in kPa (gauge)
Vp55 = Vapour pressure at 55°C.

The following examples using Diethyl ether and Acetic acid are given corresponding to paragraphs a) through c) above:

Vapor Pressure data:

Diethyl ether:	Air	Acetic acid
Vp50 =171 kPa Vp55 = 197.6 kPa	Vp55 = 115.37 kPa	Vp50 = 7.3 kPa Vp55 = 9.3 kPa

Pressure differential calculations for diethyl ether:

a) P = ((197.6 + 115.37) - 100)) x 1.5 = 319.5 kPa
b) P = ((171 x 1.75) - 100) = 199.25 kPa
c) P = ((197.6 x 1.5) - 100) = 196.4 kPa

Result: Minimum required pressure differential for a package containing diethyl ether = 196.4 kPa
Note: The required test pressure for packages subject to the provisions of 6;4.5 is 250 kPa.

For acetic acid:

a) P = ((9.33 + 115.37) - 100)) x 1.5 = 37.1 kPa
b) P = ((7.33 x 1.75) - 100) = -87.2 kPa
c) P = ((9.33 x 1.5) - 100) = -86 kPa

Result: Minimum required test pressure for a package containing Acetic acid = 75 kPa (because it is a liquid in Class 3, PG III).