International Civil Aviation Organization

WORKING PAPER

DANGEROUS GOODS PANEL (DGP)
MEETING OF THE WORKING GROUP OF THE WHOLE

Auckland, New Zealand, 4 to 8 May 2009

Agenda Item 2: Development of recommendations for amendments to the *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284) for incorporation in the 2011/2012 Edition
2.4: Part 4 — Packing Instructions

PRESSURE DIFFERENTIAL CAPABILITY REQUIREMENTS

(Presented by R. Richard)

SUMMARY

This paper presents information for consideration by the DGP Working Group with respect to the packaging performance tests for determining pressure differential capability for packagings in Part 4 and Part 6 of the Technical Instructions.

Action by the DGP-WG is in paragraph 2.

1. INTRODUCTION

1.1 At the Dangerous Goods Working Group of the Whole meeting in Dubai, April 2003 (see IP/13 and Flimsy No. 5), it was suggested that the Dangerous Goods Panel (DGP) consider clarifying the requirements for meeting the pressure differential capability requirements for packagings in 4.1.1.6 of the TI. It was also noted that the 95 kPa capability requirement may not be a true representation of the pressure differential that packagings experience in air transportation and that the vapour pressure formulas used to determine the appropriate pressure differential for high vapour pressure substances, mixtures and solutions are overly complex and difficult for shippers to apply. At the same meeting, a guidance document was presented indicating how pressure differential capability could be verified by testing for rigid containers. Following this discussion, a proposal at the DGP19 Meeting in Montreal, October 2003 (see WP/52) recommended the addition of a note to provide necessary guidance in the TI. The TI was subsequently amended to include guidance that indicates in more precise terms what is meant by "*being capable*" but specific test methods have not been adopted. The TI suggest that the capability of a packaging to meet the pressure differential performance standard should be determined by testing, with the appropriate test method selected based on packaging type (see "Note" following 4.1.1.6). The note was adopted with the view that additional work was necessary to specify appropriate test methods to ensure a more consistent approach for verifying that packagings are safe for air transport and to simplify the pressure differential requirement in order to improve overall compliance and enhance packaging integrity.

1.2 Incident data and compliance verification testing of packagings that are available in the marketplace and intended for air transport indicate that a number of the packagings offered for air transport are not able to withstand pressure differential conditions normally incident to air transportation. The packagings of most concern are packagings that must be "capable" of meeting pressure differential requirements, but are not required to be certified as meeting a specific performance test method to verify compliance with pressure differential performance standards. Incident data continues to show that packagings are leaking aboard aircraft and it is believed that this is in part attributable to the fact that the TI do not specifically provide test methods for determining that packagings meet the minimum pressure differential performance necessary to withstand conditions of air transport. It cannot be overly emphasized, however, that any incident, such as a package failure, involving hazardous materials in air transportation is unacceptable. Even a seemingly "minor" incident could quickly escalate and result in irreversible, possibly catastrophic, consequences. A discussion of the incident data analysis conducted in the US and the effects of pressure differentials on packaging closures can be found in the document available at: http://edocket.access.gpo.gov/2008/pdf/E8-15372.pdf.

1.3 When packages reach high altitudes during transport, they experience low pressure on the exterior of the package. This results in a pressure differential between the interior and exterior of the package since the pressure inside remains at the higher ground-level pressure. Higher altitudes create lower external pressures and, therefore, larger pressure differentials. This condition is especially problematic for combination packagings containing liquids. When an inner packaging, such as a glass bottle or plastic receptacle, is initially filled and sealed, the cap must be tightened to a certain torque to obtain sealing forces sufficient to contain the liquids in the packaging. This will require certain forces to be placed upon the bottle and cap threads as well as the sealing surface of the cap or cap liner to ensure the packaging remains sealed. Once at altitude, due to the internal pressure of the liquid acting upon the closure combined with the reduced external air pressure, the forces acting on the threads and the forces acting on the sealing surfaces will not be the same as when the packaging was initially closed. Under normal conditions encountered in air transport (26 kPa @ 8000 ft), conditions are not overly severe. However if the compartment is depressurized at altitude or if the compartment is not pressurized at all (e.g., feeder aircraft), the pressure differential may be severe enough to cause package failure and release of the dangerous goods in the aircraft.

1.4 Currently the Technical Instructions do not specify appropriate methods for verifying that a packaging meets the pressure differential requirement. As a result, some shippers and packaging manufacturers have used historical data (i.e., lack of incidents) and other methods (e.g. computer modelling, analogies or engineering studies) to demonstrate that their packagings satisfy the pressure differential capability requirement. Competent authorities have differing views on how the requirements are to be verified and specify various test methods for demonstrating compliance. This leads to a non-uniform approach. Competent authorities and enforcement agencies have no way of verifying whether a package meets the pressure differential requirement because no test report, documentation or other proof of compliance is required by the TI. Some less than conscientious shippers and packaging manufacturers have been known to take advantage of the lack of specific requirements for verifying compliance while others may be simply confused by the lack of specificity. Even the most conscientious and safety focused shippers have difficulty understanding how to comply with the requirements in 4.1.1.6 of the TI. The fact that specific test methods are not specified in the TI leads to inconsistencies in package integrity and results in varying levels of compliance among shippers. This leads to wide disparities in packaging quality and the potential for sub-standard packages to be introduced into the air transport environment and increases the probability of releases of dangerous goods aboard aircraft In addition, some shippers or manufacturers may not realize that both UN certified packaging and packagings that are not required to meet the UN performance tests are subject to the pressure differential capability requirements. This would include packagings for products, such as limited quantities and consumer commodities. A significant percentage of aircraft incidents involving hazardous materials appear to result from failures of these packagings. The introduction of specific test methods and amendments that simplify the requirements will lead to enhanced safety of packagings intended for air transport.

1.5 In addition to discussing methods of verifying compliance with the pressure differential requirement, it is also suggested the Panel discuss whether the currently specified pressure differential is appropriate. Considering the fact that Note 3 in the Introduction to Part 4 states "Due to altitude, pressure reductions will be encountered under flight condition which may in extreme conditions be of the order of 68 kPa…." it is suggested that the DGP working group consider if the current 95 kPa pressure differential capability standard is appropriate. Aircraft cargo compartments are typically pressurized to an altitude of 2,438m (8,000-ft) resulting in a pressure differential of approximately 26kPa on packages filled at or near sea level. Non-pressurized "feeder aircraft" typically fly at approximately 3,963-4,877m (13,000-16,000 ft). The highest recorded altitude in a non-pressurized feeder aircraft was 6,017m (19,740 ft). Based on these findings, it is evident that packaged products transported by the feeder aircraft network used by air cargo carriers may experience potential pressure differentials of approximately 55 kPa. The current pressure differential standard provides a significant level of safety, but is not in all cases practical to demonstrate through testing. The DGP working group is requested to consider whether the 95 kPa pressure differential is appropriate or whether a more practical pressure differential value (e.g. 60 kPa, 68 kPa or 75 kPa)would be more appropriate to facilitate compliance, while still ensuring that the capability of packagings would be held to a higher standard than is typically experienced under conditions experienced in air transport. The following table details the pressure differential typically experienced at various altitudes:

Pressure Conversion Table				
	Altitude (meters)	Altitude (feet)	kPa	Pressure Differential (A- #)
A	0	0	101.3	101.3 kPa
1	305	1,000	97.7	3.6 kPa
2	2,438	8,000	75.3	26 kPa
3	4,267	14,000	59.5	41.8 kPa
4	4,877	16,000	54.9	46.4 kPa
5	6,096	20,000	46.6	54.7 kPa
6	9,144	30,000	30.1	71.2 kPa
7	15,240	50,000	11.6	89.7 kPa

1.6 Two appendixes have been added to provide information on a number of industry consensus standards that address pressure differential testing. Appendix A describes the low pressure hydrostatic pressure test method suitable for air inner packages. Appendix B addresses a combination of pressure differential and vibration tests. It provides an overview of three tests that may be conducted in order to ensure that packaging materials can withstand vibration as well as meet a pressure differential standard. The working group is requested to consider if these methods are acceptable and if other standards are appropriate and should be equally considered. It is envisioned that a list of acceptable test methods could be incorporated into the TI. A summary of the relevant industry standards is provided in Appendixes A and B, and a link from which they may be downloaded via the internet is provided in Appendix A.

1.7 The DGP working group should note that many of these industry testing standards use 60 kPa as the recognized pressure differential capability necessary to ensure the package design is capable of meeting air transport conditions. The DGP working group is encouraged to consider whether this level of capability is appropriate. Additionally, the DGP working group is encouraged to discuss the usefulness of the vapour pressure calculations that allow for varying pressure differential requirements depending on the vapour pressure of the contained liquid on the basis that for mixtures and solutions containing more than one regulated constituent, this calculation can be extremely difficult and overly complex. Finally, the DGP working group is also requested to consider including specific references to standards that specify methods for determining pressure differential capability and requirements that the shipper or packaging manufacturer provide proof of compliance documentation (e.g. test report) with the goal of enhancing packaging integrity, uniformity, simplicity and safety.

2. ACTION BY THE DGP-WG

2.1 The DGP-WG is invited to consider and provide comments and feedback on the Packaging Performance Tests, in Part 4 and Part 6 of the Technical Instructions. Based on feedback received and discussions at the present meeting, a formal working paper may be submitted for the October Dangerous Goods Panel meeting.

For Consideration and Comment:

2.2 Part 4 amendments could be presented as follows:

1.1.6 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~~[60] 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 = (V_{p50} × 1.75) – 100 kPa with a minimum of 95 kPa~~

~~where~~

~~P = Pressure requirement in kPa (gauge)~~

~~V_{p50} = 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 = (V_{p55} × 1.5) – 100 kPa with a minimum of 95 kPa~~

~~where~~

~~P = Pressure requirement in kPa (gauge)~~

~~V_{p55} = Vapour pressure at 55°C.~~

Note.— The capability of a packaging to withstand an internal pressure without leakage that produces the specified pressure differential should be determined by testing samples of inner packagings of combination packagings and single packagings. Pressure differential is the difference between the pressure exerted on the inside of the packaging and the pressure on the outside. The appropriate test method should be selected based on packaging type. Acceptable test methods include any method that produces the required pressure differential between the inside and outside of a single packaging or an inner packaging of a combination packaging. Relevant test methods are identified in Part 6 Chapters 4 and 4.9, which also provide additional guidance on testing inner packagings to determine the pressure differential. ~~*The test may be conducted using internal hydraulic or pneumatic pressure (gauge) or*~~

~~*external vacuum test methods. Internal hydraulic or pneumatic pressure can be applied in most cases as the required pressure differential can be achieved under most circumstances. An external vacuum test is not acceptable if the specified pressure differential is not achieved and maintained. The external vacuum test is a generally acceptable method for rigid packagings but is not normally acceptable for:*~~

~~— *flexible packagings;*~~

~~— *packagings filled and closed under an absolute atmospheric pressure lower than 95 kPa or for liquids in Packing Group III of Class 3 or Division 6.1 with an absolute pressure of 75 kPa;*~~

~~— *packagings intended for the transport of high vapour pressure liquids (i.e. vapour pressure greater than 111 kPa at 50°C or 130 kPa at 55°C and accordingly greater than 100 kPa at 50°C or 117 kPa at 55°C for liquids in Packing Group III of Class 3 or Division 6.1.*~~

2.3 Amendments to Part 6 could be considered as follows:

4.5.1 Packagings to be tested: the internal pressure (hydraulic) test must be carried out on all design types of metal, plastic and composite packagings intended to contain liquids. This test is not required for the inner packagings of combination packagings. For the internal pressure requirements for inner packagings see 4;1.1.6.1.

Note:— This test may also be used for inner packagings of combination packages containing liquids (see 4.9 of this chapter).

. . .

Add in 4.9 Pressure Differential Testing Guidance for testing inner packagings to read as follows:

4.9.1 In accordance with the requirements of Part 4 Chapter 1.1.6, a combination packaging containing liquids must be capable of withstanding an internal pressure without leakage that produces the specified pressure differential. This should be determined by testing samples of inner packagings of combination packagings. Each inner packaging design type used in a combination packaging intended to contain liquids must be capable of withstanding an internal pressure that produces a pressure differential of 60 kPa without leakage. The capability of an inner packaging to withstand the pressure differential should be determined by testing samples of inner packagings intended for use in combination packagings and single packagings. Pressure differential is the difference between the pressure exerted on the inside of the packaging and the pressure on the outside. The appropriate test method should be selected based on packaging type. Acceptable test methods must produce the required pressure differential between the inside and outside of a single packaging or an inner packaging intended for use in a combination packaging. A test report or record of the test must be maintained and provided to the competent authority upon request. Acceptable test methods include:

Test	**Equipment**	**Time under Pressure**	**Pressure Differential**
6;4.5	Pressure fitting, pump.	5 minutes for metal and composite (including glass, porcelain, or stoneware); 30 minutes for plastic	60 kPa differential.
(b) ASTM D6653-01	Vacuum chamber and associated gages and pumps.	60 minutes	14,000 ft (41.8 kPa differential)[1] or 16,000 ft (46.4 kPa differential)[2]
(c) ASTM D4991-94	Transparent vessel capable of withstanding 1-1/2 atmospheres, inlet tube and vacuum pump, moisture trap, solution of ethylene glycol in water.	30 minutes for plastic, 10 minutes for everything else	60 kPa pressure differential.
(d) ASTM F1140 or Part 178 Appendix D for flexible packaging	Inlet tube	30 minutes	60 kPa pressure differential
[1] If it is not possible to use the atmospheric and temperature pre-conditioning specified. [2] For test specimens where the atmospheric and temperature pre-conditioning is followed.			
(a) ISTA 3A	Individual packaged products weighing 150 lbs. or less; air or ground transportation	• Atmospheric Preconditioning • Shock (drop) • Vibration (random with and without top load) • Vibration (random under vacuum) • Shock (drop	The section for random vibration under pressure is optional. When conducted, the pressure and vibration are simultaneous. A pressure approximately equal to an altitude of 10,000 ft is used for 60 minutes.
(b) ASTM 4169 Distribution Cycle 12	Air (intercity) and motor freight (local), over 100 lb, unitized.	• Handling • Stacked Vibration • Low Pressure • Vehicle Vibration and Handling	Low pressure section instructs packages to be tested at pressure of expected altitudes. If not known, refer to ASTM D6653, which specifies 14,000 ft for 60 minutes. See ASTM 4169 for vibration details.
(c) ASTM 4169 Distribution Cycle 13	Air (intercity) and motor freight (local), single package up to 100 lb.	• Handling • Vehicle Stacking • Loose-Load Vibration • Low Pressure • Vehicle Vibration and Handling	Low pressure section instructs packages to be tested at pressure of expected altitudes. If not known, refer to ASTM D6653, which specifies 14,000 ft for 60 minutes. See ASTM 4169 for vibration details.

— — — — — — — —

APPENDIX A

LOW PRESSURE HYDROSTATIC PRESSURE TEST METHOD SUITABLE FOR AIR INNER PACKAGES

Recent studies have simulated the impact of high-altitude on package integrity. The conditions that packages experience in the air transport shipping environment have been demonstrated by measurement studies with test protocols designed around these results. The studies have resulted in test protocols being developed under industry standard groups such as ASTM and ISTA. These tests can be reviewed by accessing the following link:

http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=PHMSA-2007-29364

Test	Equipment	Time under Pressure	Pressure Differential
(a) 6;4.5.1	Pressure fitting, pump.	5 minutes for metal and composite (including glass, porcelain, or stoneware); 30 minutes for plastic	60 kPa differential.
(b) ASTM D6653-01	Vacuum chamber and associated gages and pumps.	60 minutes	14,000 ft (41.8 kPa differential)[1] or 16,000 ft (46.4 kPa differential)[2]
(c) ASTM D4991-94	Transparent vessel capable of withstanding 1-1/2 atmospheres, inlet tube and vacuum pump, moisture trap, solution of ethylene glycol in water.	30 minutes for plastic, 10 minutes for everything else	60 kPa pressure differential.
(d) ASTM F1140 or Part 178 Appendix D for flexible packaging	Inlet tube	30 minutes	60 kPa pressure differential

[1] If it is not possible to use the atmospheric and temperature pre-conditioning specified.
[2] For test specimens where the atmospheric and temperature pre-conditioning is followed.

(a) 6;4.5.1 – Low Pressure Hydrostatic Pressure Test Method Suitable for Air Inner Packages. This test is currently required for all single and composite packagings intended to contain liquid, but it is not currently required for inner packagings of combination packaging. This test, which uses the hydrostatic test method, pumps high pressure water into a packaging to create a pressure differential. Failure is determined if there is leakage of liquid from the package during the test. This could be observed as a stream of liquid exiting the package or rupture of the package.

(b) ASTM D6653-01 – Standard Test Methods for Determining the Effects of High Altitude on Packaging Systems by Vacuum Method. This method uses a vacuum chamber to determine the effects of pressure differential on packages. Upon completion of the test, the package is removed and checked for damage in the form of package failure, closure failure, material failure, internal packaging failure, product failure, or combinations thereof. If these are all free of damage, then the packaging should be reassembled for testing in accordance with an industry accepted packaged product performance test, such as Practice D 4169. This will help determine if the pressure differential conditioning had an effect on the performance of the packaging system.

(c) ASTM D4991-94 (Reapproved 1999) Standard Test Method for Leakage Testing of Empty Rigid Containers by Vacuum Method. This test is applied to empty packagings to check for resistance to leakage under differential pressure conditions, such as those that can occur during air transport. Instead of pumping high-pressure air into the packaging, the air pressure on the exterior of the packaging is reduced using a vacuum. The package is considered to fail if it leaks a continuous stream or recurring succession of bubbles or if fluid is found within the test specimen after the test.

(d) ASTM F 1140 – Standard Test Methods for Internal Pressurization Failure Resistance of Unrestrained Packages for Medical Applications. For flexible packaging (e.g., bags), we are proposing to require the pressure differential test to be performed in accordance with ASTM F 1140 or the alternative listed in Part6; Chapter 4.7.2.

— — — — — — — —

APPENDIX B

COMBINATION OF PRESSURE DIFFERENTIAL AND VIBRATION TESTS

This appendix contains information relative to a combination of vibration and pressure differential testing on the same inner packaging.

"Combination" Pressure Differential and Vibration Tests.

The following three combination tests are voluntary industry standards that are being used by a number of shippers currently. Additional details regarding these standards can be found in the following table and in the discussion following the table:

(a) ISTA 3A	Individual packaged products weighing 150 lbs. or less; air or ground transportation.	• Atmospheric Preconditioning • Shock (drop) • Vibration (random with and without top load) • Vibration (random under vacuum) • Shock (drop)	The section for random vibration under pressure is optional. When conducted, the pressure and vibration are simultaneous. A pressure approximately equal to an altitude of 10,000 ft is used for 60 minutes.
(b) ASTM 4169 Distribution Cycle 12	Air (intercity) and motor freight (local), over 100 lb, unitized.	• Handling • Stacked Vibration • Low Pressure • Vehicle Vibration and Handling	Low pressure section instructs packages to be tested at pressure of expected altitudes. If not known, refer to ASTM D6653, which specifies 14,000 ft for 60 minutes. See ASTM 4169 for vibration details.
(c) ASTM 4169 Distribution Cycle 13	Air (intercity) and motor freight (local), single package up to 100 lb.	• Handling • Vehicle Stacking • Loose-Load Vibration • Low Pressure • Vehicle Vibration and Handling	Low pressure section instructs packages to be tested at pressure of expected altitudes. If not known, refer to ASTM D6653, which specifies 14,000 ft for 60 minutes. See ASTM 4169 for vibration details.

ISTA 3A – This is part of a series of general simulation tests that are meant to recreate the hazards of a distribution environment. It is similar to ASTM 4169 because it requires rather sophisticated, extensive, and expensive equipment (such as a random vibration table with appropriate instrumentation) and relatively skilled operators. Unlike D4169, however, there are a number of specific procedures, covering a number of packaged products and distribution systems, so much less interpretation is required. This procedure includes shock and vibration testing with an option to include simultaneous pressure testing during one of the random vibration phases.

ASTM 4169 Distribution Cycle 12 – This is the only ASTM standard devoted to packaged product performance in distribution. It is a pre-shipment general simulation test covering a range of packaging types and distribution scenarios. For example, it lists 18 distribution cycles that each represents a different mode or environment. There is a prescribed sequence of performance tests for each of these distribution cycles. Air transportation is covered in Distribution Cycles 12 and 13. These cycles include several types of vibration and pressure testing. However, these are performed sequentially, unlike ISTA 3A, which has the option to perform vibration and pressure testing simultaneously. Distribution Cycle 12 tests are for unitized freight that weigh over 100 lbs. More details on the sequence of testing can be found in the previous table.

ASTM 4169 Distribution Cycle 13 – Distribution Cycle 13 tests are for loose-load freight weighing under 100 lbs. The prescribed tests specify an additional vibration test to simulate the more aggressive shipping environment. More details on the sequence of testing can be found in the previous table.

— END —