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AIR PACKAGING NPRM: DANGEROUS GOODS LIQUIDS IN COMBINATION PACKAGES TRANSPORTED BY AIR RULE

Rule Commentary by:
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On May 14, 2010, PHMSA published a NPRM [Docket No. PHMSA-07-29364 (HM-231A)]. This rulemaking process began with a public meeting held on June 21, 2007, to discuss leaking inner containers of combination packages aboard aircraft. It was followed with an ANPRM [PHMSA-07-29364 (HM-231A)] published in July 7, 2008.

Background to rulemaking

PHMSA believes that an analysis of incident data collected over previous years reveals a pattern of packaging failures that is above an acceptable range (which it set at zero), and that this type of failure should be addressed with a rulemaking to enhance package design and testing. This was the beginning of a process that will likely end in 2011 with the publication/adoption of a final rule. Note that PHMSA points out that the new packaging requirements that were incorporated in the re-formatting of the ICAO TI will come into effect on January 1, 2011. These must be reviewed and understood as they do prescribe some new packaging requirements.

Throughout this rulemaking process there has been plenty of discussion of the nature of the problem and of the proper form of a solution. The incident data was insufficiently granular to identify some of the potential problem packaging types. The packaging tests that DOT/FAA commissioned were not designed well enough to provide some key data upon which to base sound engineering conclusions. But, this rulemaking mostly respects these limitations in knowledge. This NPRM, with certain exceptions, seems to be a reasonable path forward to achieve the goal PHMSA has set of reducing leaking inner containers of combination packages in air shipments to no reported incidents of released hazardous materials. I wish them luck with this goal and there are sensible solutions to real problems contained in this NPRM.

Introduction

The proposed regulatory activity can be summarized into four general categories: (1) additional clarifying language to the regulations prescribing applicability and responsibility for meeting the requirements of 173.27; (2) requiring a test to demonstrate the required pressure differential capability, standardizing the test methods including incorporation of recognized industry test procedures as well as inclusion of test methods in an Appendix to Part 173 [Appendix E]; (3) proposing a "layered" approach in packaging design that would include secondary containment, secondary closure (or closure retention) features; (4) simplifying the determination of the required minimum test pressure based upon the requirements of 173.27(c).

PHMSA proposes to revise the language of CFR 49 §173.27 to clarify that all packaging types not already tested and marked under the requirements of CFR 49 §178.603 (thus all combination packagings, including non-specification packagings) are subject to the requirements of 173.27, including the expanded 173.27(c) and Appendix E. There has long been a problem in the shipping community in making persons aware that limited quantity shipments by air have some package performance requirements. There is no obvious "path" through the CFR 49 that leads a shipper to this requirement, so it is labeled –general requirements–and is referenced several times throughout the

HMR to make persons aware of this special requirement. To be fair, this is also a problem with the structure of international regulations since I believe it is un-common to find shippers that realize limited quantity packages shipped under international air regulations have drop and stack performance requirements. The proposed changes do not really address this problem. Only through increased emphasis in training and enforcement will these general packaging requirements become common knowledge.

Testing required demonstrating pressure differential capability

This change seemed inevitable. I believe that it will reduce the number of leaking packages offered for air transport when widely practiced, particularly when applied to non-specification (limited quantity) packages.

What is to be applauded here is PHMSA's openness to methodological pluralism. PHMSA adds an Appendix E to Part 173 that incorporates by reference several industry standard tests [ASTM: D 3078, D 4991, D 6653, F 1140; ISTA 3A] as long as the vibration and pressure differential components of the tests are included. Particular test methods are specified that can be followed without need to involve outside standards, as well as incorporating the widely used hydrostatic test method already in CFR 49 178.603 for pressure testing single/composite packagings for transporting liquids. All are listed as suitable methods to demonstrate capability. This obviates the need to perform multiple tests on the same package when a shipper has utilized one of the tests incorporated into the regulations.

PHMSA expresses an opinion in the rulemaking that the tests incorporating simultaneous vacuum and vibration are superior tests for predicting packaging performance in real world shipping environments. This may be true, but the tests the agency had performed were not properly designed to demonstrate this opinion. And, if this is the case, how can it be that the average loss from failure in the test packagings is .5 grams (cc) of water, but the average reported loss quantity from the incident reports is .5 gallons? The most logical explanation of this disparity is that screw cap closures were not the culprits in most of the reported incidents. The losses reported in transportation were likely the result of friction plug paint cans being shipped without locking rings (the reported hazard classes and proper shipping names are consistent with this). When these friction plugs unseat, the entire contents of a can be quickly lost. In the case of threaded closures the mode of failure will be seepage or dripping, but fundamental containment is not lost. In closed combination packagings, a .5 gram leak/bottle would not likely be detectable and hence would not generate an incident report.

In the end, the proposal to allow for several test methods to demonstrate pressure capability is defensible and the most convenient and cost effective for the shipping community. There will surely be many container/closure combinations that will no longer be eligible for use in packaging liquid hazardous materials by air when evaluated by any of the specified tests, but that is the point of the test program undertaking.

Layered containment strategies

This is where the proposed rule gets close to going off the rails from a package engineering standpoint.

PMSA proposes to incorporate the requirements contained in the new packaging instructions in ICAO, that will be in effect January 1, 2011. In these is a specific requirement that:

"1.1.4 The body and closure of any packaging must be so constructed as to be able to adequately resist the effects of temperature and vibration occurring in normal conditions of transport. Closures must be held securely, tightly and effectively in place by secondary means. Examples of such methods include: adhesive tape, friction sleeves, welding or soldering, positive locking wires, locking rings, induction heat seals and child-resistant closures. The closure device must be so designed that it is unlikely that it can be incorrectly or incompletely closed.

1.1.4.1 When secondary means of closure cannot be applied to an inner packaging containing liquids the inner packaging must be securely closed and placed in a leakproof liner and then placed in an outer packaging."
PHMSA proposes to adopt this requirement into the CFR 49 173.27(d).

Types of closures

Let me start by pointing out that Child Resistant (CR) closures are designed to be, well, child resistant. I had not realized that the examination of incident data had revealed that the likely cause of leakage was packages being transported in ULDs containing kindergarten classes. I asked several representatives in the community of regulators, from both PHMSA and international organizations, to explain to me the mechanism by which any commonly available CR feature would enhance the retention of the sealing capability of the closure under the effects of internal pressure/temperature change/vibration. I have yet to hear a plausible explanation.

There are cases where some CR features (such as the two-piece closures with over-caps) will perform well in a drop test. This is because the outer shell will absorb impact forces and may break, but in the process offers some protection to the inner component which actually effects the seal and performs the containment function. But, this is not the issue here. As a matter of fact, the US, senior-friendly requirements adopted into the CR regulations forced many CR closure manufacturers to reduce the amount of thread engagement on CR closures to about 270 degrees. This was in order to reduce off torque (the primary CR feature being the requirement to perform two actions simultaneously, i.e. push and turn), thus reducing the non-back off capability of the closure. Other types of CR features (push tabs with posts, etc.) will function as a non-back off feature, but are not designed to and would not prevent sufficient back off to compromise internal pressure capability anyway. And, DOT/FAA testing showed that even in instances of closure failure during testing, closure back off was not detected. There is no evidence that threaded closure back off is the cause of leaks.

It is also curious that other types of non-back off features far more effective than tape or shrink bands are not mentioned, e.g., closures designed with a specific non-back-off (NBO) feature with a corresponding feature on the neck finish. Many types of external tamper indicating features such as ratchet skirts and bead-locked bands function as effective NBO features.

Features of secondary closures

These current examples of "secondary closure" in the regulations no doubt began as a solution to the problem of retaining linear friction closures during the rigors of transport. As a rule this type of closure can be more easily displaced by shock, vibration and internal pressure than threaded closures. Once this process of displacement begins it advances rapidly since the usual design of linear friction closures results in any back out easing further back out as surface contact area is reduced and native taper reduces the remaining force normal at the sealing interface. Several of these types of closures are very effective if the back out can be arrested. Crimp collars, wire retained stoppers, and paint can plugs with locking rings are probably the paradigm examples of these systems. Tape is often a less effective means since it will also "relax" over time as a result of application stress and adhesive degradation. So shelf storage reduces its effectiveness as surely as it would the closure it is meant to secure. The reality is that linear friction style closures will require quite effective retention mechanisms to pass the required pressure differential tests at all. By the time the total design is capable of maintaining the required internal pressure this additional design requirement would be superfluous. This is the reason this rulemaking should focus on getting the containers tested. The designs that prove capable of passing the required tests will not require this kind of ad hoc treatment to remain effective in transportation.

For threaded closures, this function is more complicated to achieve. It is likely that the overwhelming percentage of leaks from containers with threaded closures that start life as pressure capable, result from some combination of stress-induced relaxation (cold flow) reducing the force normal at the sealing surface and/or liner set for closures utilizing them. The listed secondary retention features are usually not themselves liquid-tight. Unless specially designed to maintain the required force normal on the sealing surface (I know of no such commercially available product), they will not prevent seepage from the closure during external depressurization if the primary closure surface is compromised.

Shrink bands would suffer near identical drawbacks as a secondary retention method. And, neither of these methods provides reliable secondary sealing or containment capacity. Plastic containers with plastic closures will lose sealing force over time whether taped or banded ; and this loosening is not a result of thread back off that the listed examples of secondary closure applicable to commonly used packagings can arrest. Also, tape can be applied in a manner (the wrong winding direction) that can actually cause the closure to back off.

Assuring proper closing

If a properly closed bottle is leak-tight at the required pressure differential, the surest way to contain the product for transportation is making certain the cap is closed to the required torque as close as practicable to the time it will be shipped. A well-designed, tested and properly closed container is the safest to ship.

It should also be noted that induction sealed liners are not an example of secondary retention or closure means at all—they are a very effective primary sealing mechanism for this purpose when compatible with product and processes. They are very effective because, when properly formed, their sealing capability becomes largely insensitive to retained closure torque (hence shelf storage time.) As long as the threads on the closure are sufficiently engaged to keep the closure shell on the bottle, it will remain leak tight. (I have tested several varieties that will not leak at 95 kPa internal pressures with the outer caps completely removed.)

I point this out to agree with PHMSA that an induction sealed container is very unlikely to leak in transport if properly closed. But this only emphasizes the futility of the other means listed if the primary sealing surface is incompetent. Tape, tamper bands and the like will not maintain sufficient sealing force at the land, and will be unlikely to contain the seepage that results.

Oversights in some closure considerations

I am not arguing that there are no circumstances ever that the listed examples of secondary closure would not make a positive contribution to safety. And, I know that not all regulatory activity is driven by pure engineering considerations. But this part of the proposed regulation seems poorly thought through and can add significant cost and trouble to packaging users and designers for very little additional safety benefit. This type of design confusion can also introduce market distortions that reduce safety as the example below demonstrates.

The photo on the left is a 38-400, Push and Turn, CR closure representative of many commonly used on plastic bottles. It most often will only have 270 degrees (3/4 turn) of thread engagement, with the inner threaded shell sometimes manufactured on jump thread molds, resulting in shallower, more rounded threads. But, when mated with well-made neck finish on a bottle and properly closed, several will withstand a 95 kPa pressure differential, and would be considered to have a “secondary closure retention feature” incorporated per the examples of such listed in the language of the proposed regulation.

The closure on the right is a 38-439, CT, injection molded closure known in the industry as an “Acid Cap.” It utilizes two full turns of thread engagement with a very heavy thread and is manufactured using unscrewing molds to deepen the thread pattern. And crucially, for our purposes, a very deep body (large "H" dimension) that is one of the design features most sought for robust closures. When on a glass or well-made heavy walled plastic bottle, properly closed it will withstand 250 kPa (and probably more) of internal pressure. Yet, under the proposed regulation, a shipper using this closure would be required to use tape, shrink sleeves or some other equally superfluous and inferior "secondary means of closure retention"; or resort to a liner bag as a secondary means of containment. This, while the inferior CR closure could be shipped without package liners or additional protection—and at significantly reduced cost to the shipper. This is how a regulation can distort a market and reduce transportation safety.

Anyone with any experience with these packaging systems would immediately recognize the perversity of a proposed regulation that produces this situation. The regulations should be fashioned to recognize the superior safety of the closure on the right, and certainly should not impose any further financial burden on shippers selecting it for their package.

Liners and bags

For those unlucky souls with bottle/closure systems that have no features that could be considered a "secondary means of retention" and there is no real way to apply them, they will now proceed to the "leak-proof liner" (secondary containment) requirement to meet the proposed regulations. A note of caution to PHMSA and shippers on the use of the phrase "leak-proof liner" in the regulations. Standard commercially available liner bags (usually LDPE or LLDPE) are not manufactured, sold or otherwise represented as "leakproof." Leakproof bags are available, but are made to much more precise standards and on lines that have testing capabilities to demonstrate and document "leakproofness". They carry a correspondingly high price tag. Perhaps the phrase "liner bag or other effective means of secondary liquid containment" should be contemplated.

Also of note in this section of the proposed rule is the incorporation of the new ICAO requirement that all PG I liquid hazardous materials be packaged with the primary receptacles fitted with secondary means of closure, *further enclosed in a "rigid leakproof liner or rigid intermediate packaging" with sufficient absorbent for the entire contents of the inner packaging*. I am unsure of what is meant by making a distinction between a "rigid leakproof liner" or "rigid intermediate packaging". And, in the context of designing a packaging to meet this requirement I would like to see this clarified; particularly if it is related to the possibility of placing more than one primary receptacle per intermediate packaging. The proposed regulation uses the singular. Perhaps the rigid liner would allow for multiple, protected inner packagings in a single intermediate packaging with sufficient absorbent material for all the primary receptacles. This should be made clear.

Simplifying the determination of minimum test pressures

There have been few experiences in my years of developing and testing packaging systems for shipping hazardous materials as frustrating as trying to determine minimum required test pressures for both hydrostatic capability of single/composite packagings [CFR 49 § 173.24a(b)(4)/178.605(d)] and the internal pressure capability requirements for air shipments of liquid hazardous materials in the general requirements for air shipments in [CFR 49 § 178.27(c)]. given the usual paucity of available physical data for the material that the shipper can provide.

In this proposed rule, PHMSA in cooperation with BAM has performed a real public service to the hazmat shipping community. It has made a significant contribution to safety by incorporating alternative methods of determining these minimum required test pressures based upon more readily available information from a properly constructed MSDS and a set of safe boundary assumptions.

Focusing on CFR 49 173.27(c), we have wrestled with the logic of this regulatory requirement:
Minimum test pressure capability must be the greater of X or Y. Where X is the famous 95 kPa minimum (except for the 75 kPa materials—Class 3 and Division 6.1 of PG III) and Y is a value determined by one of three methods based either on the vapor pressures of the materials at elevated temperatures, or a direct measurement (gauge pressure) of pressure in the packaged product, filled at an initial temperature then heated to an elevated

temperature. Of course, one cannot satisfy the logic of this requirement unless both values are known (as DOT has said in letters of clarification.) When discussing this with shippers over the years (I always prefer this conversation on the phone.), the range of reactions has been…interesting. The usual result has been: “I need something capable of 95 kPa.” And we move on.

PHMSA proposes to incorporate a table in Appendix E of Part 173 that allows for the straightforward use of the initial boiling point (usually readily available on the MSDS) or a vapor pressure at 50 deg C (one of the current standards, but more difficult to obtain so this not much of an improvement) to determine the minimum required test pressure for the receptacle. The proposed rule also allows for the use of these values attributed to the single worst case (highest vapor pressure or lowest initial boiling point) constituent material in a compound as a boundary condition. This is often done in practice, but it is helpful to have it codified into the regulations. I will leave it to the chemists to comment on the scientific validity of the proposed rule, but do not expect to hear much since they (as a group with some welcome exceptions) often do not show much interest in the HMR.

This required information is much more readily available for constituent components, and creates boundary conditions that can alert shippers of materials, as rare as they are, that would exceed the 95 kPa minimum requirement. (Now, if we could just get marketing to allow some headspace in those retail containers the industry may actually be able to ship packages that comply with the regulations.)

Conclusion

Having been involved with this rulemaking cycle from the beginning (I attended the public meeting), I have been impressed by the interaction between PHMSA and industry. Much of the best of these exchanges have been incorporated into the proposed rule; each iteration of the process obviously incorporating the feedback from the previous.

The incidents of leakage in air transport that rightfully worry PHMSA are very likely the failure of packagings that have never been tested to ascertain pressure differential capability before being offered for air transport. The simple mandating of testing, particularly as it becomes widespread in the population of non-specification packagings, will very likely dramatically drive down the incidents to a very low level. Zero is probably not a realistic expectation in any human endeavor, but enhanced data gathering combined with package testing will eventually produce a population of capable and reliable packagings.

I would prefer to see the results of the testing mandate evaluated before the “secondary closure” requirements are prescribed to see if they are necessary or helpful. Their adoption into ICAO seems somewhat muddled, and incorporating that muddle into the CFR does not seem likely to improve on the situation.

There could be a decisive test program developed and executed that would offer a better rational for that part of the rule.

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