71-9305

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Date: 11/9/05 12:54PM
Subject: Draft Certification Test Plan, TRUPACT-III Package, Docket No. 71 -9305

Meraj:

In preparation for the TRUPACT-III package meeting on November 16th, please find attached a PDF file of PacTec's draft certification plan (TP-039) for the NMSS staff's use. This draft plan provides additional supporting information to the material that will be presented at the meeting, and should assist the NRC staff's understanding of the planned certification testing. Should you have any questions about this draft test plan or require further information for the meeting, please contact me.

Thank you.

Regards,

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Mail Envelope Properties (437237B8.961 : 0 : 59745)

Subject:	Draft Certification Test Plan, TRUPACT-III Package, Docket No. 71 - 9305
Creation Date:	11/9/05 12:52PM
From:	"Clark, Gary" <gclark@pactec-tn.com>
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TEXT.htm	4371	
TP-039, Rev D.pdf	962751	
Mime.822	1324641	

Options

Expiration Date:	None
Priority:	Standard
Reply Requested:	No
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Concealed Subject:	No
Security:	Standard

PACTEC

TEST PLAN

SPECIFICATION NO:	TP-039	PROJECT NAME:	TRUPACT-III Certification Activities
PROJECT NO:	51199	CLIENT:	Washington TRU Solutions, LLC

SPECIFICATION TITLE:

TRUPACT-III Transportation Package Certification Test Plan

SUMMARY DESCRIPTION:

This test plan defines and supports the certification tests to be performed on the TRUPACT-III package.

This document is Draft Revision D for discussion and comment

REV.	DCR NO.	PREPARER SIGNATURE/DATE	VERIFIER SIGNATURE/DATE	PE & PM APPROVALS SIGNATURE/DATE	QA APPROVAL SIGNATURE/DATE
0	N/A				

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1.0 INTRODUCTION

This document describes the approach used to demonstrate compliance of the TRUPACT-III transportation package with the requirements of 10 CFR §71.73 [1]. The TRUPACT-III package is a Type B(U)F-96, rectangular package with reinforced, flat walls, a bolted flange lid, and a fully enveloping overpack. The licensing basis for the TRUPACT-III package will be primarily demonstration by a full-scale test. Analysis is used for all Normal Conditions of Transport (NCT) events, except the free drop (10 CFR §71.71(c)(7)), and for the Hypothetical Accident Conditions (HAC) immersion case [10 CFR §71.73(c)(5)], and the thermal event [10 CFR §71.73(c)(4)]. Full scale testing will be used for the HAC free drop and puncture events [10 CFR §71.73(c)(1) & (3)].

The objective of the test program is to demonstrate that, after a worst-case series of free drop and puncture drop events, the full-scale, prototypic Certification Test Unit (CTU) is leaktight according to ANSI N14.5 [2], and has not incurred damage that would invalidate thermal or criticality analysis assumptions.

2.0 REFERENCES

1. Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Energy — Packaging and Transportation of Radioactive Material*.
2. ANSI N14.5-1997, *American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment*, American National Standard Institute, Inc. (ANSI).

3.0 CERTIFICATION STRATEGY

There are two primary objectives for the certification test program:

1. To demonstrate that, after a worst-case series of free drop and puncture events, the package containment is leaktight.
2. To further demonstrate that no deformations will be incurred that would lead to failure of the containment under the subsequent HAC fire event.

Several orientations will be tested to ensure that the worst-case series of free and puncture drop events has been considered. Post-impact helium leakage rate testing will demonstrate that the containment boundary is leaktight per ANSI N14.5[1].

The maximum combination of free and puncture drop deformation will be used in the thermal analysis to show that under these worst-case conditions, the elastomer O-ring seal temperature

[1] In this document, the term "leaktight per ANSI N14.5" means a leakage rate less than or equal to 1×10^{-8} Pa-m^3/s (1×10^{-7} ref-cc/sec), air.

does not exceed safe limits during the HAC fire event. In addition, it will be shown that the CSA structure does not exceed the temperature limit for the structural material.

Besides providing containment of the radioactive materials, the TRUPACT-III package must maintain a subcritical payload. However, due to the nature of the TRU waste payloads slated for transport, criticality is controlled by limiting the payload and maintaining nominal CSA geometry. And since the payload is contact handled, no biological shielding is required. Therefore, criticality and biological shielding do not need to be considered in the certification test program.

3.1 Prior Testing in Half-Scale

The TRUPACT-III package has been subject to three previous test campaigns using a prototypic half-scale test unit. In its current configuration, the TRUPACT-III package differs somewhat from the configuration tested previously, but retains its essential shape and internal structure. The differences may be summarized as follows:

Prior Configuration	*Current Configuration*
Gross weight of 30,000 kg, and maximum payload weight of 5,800 kg	Gross weight of 25,000 kg and maximum payload weight of 5,125 kg
Overall length of 6,058 mm	Overall length of 4,288 mm
Energy absorption by wood and phenolic foam	Energy absorption by polyurethane foam
No puncture-resistant plate in overpack cover; 10-mm thick plate in closed end	15-mm thick puncture-resistant plate in both ends

In addition, some structural stiffness has been added to the body and closure lid sealing flanges, and some minor construction details have been altered for better performance.

In 1994, the package, designated the TN-Gemini, was tested in France. That test series included one NCT, 0.3-m free drop, four HAC, 9-m free drops, and four punctures. After each test, both the containment seal and the containment boundary were individually leaktight per ANSI N14.5.

In 2003, the same test unit was completely refurbished, replacing the closure lid, closure bolts, and all overpack materials and structures external to the CSA. The subsequent test series was conducted at Sandia National Laboratories (free drops) and at a private contractor in Carlsbad, NM (punctures), and included one NCT, 0.3-m free drop, three HAC, 9-m free drops, and four punctures. Once again, the containment seal and containment boundary were leaktight subsequent to all testing.

Finally, in 2005, the puncture-resistant structures on the closed end (also representative of the structures in the overpack cover) were refurbished and tested to determine the effectiveness of design changes made subsequent to the Sandia tests. Several punctures were performed on the package sides in order to confirm the worst-case puncture attack angle to be used in certification testing. Additionally, a 9 m free drop onto the large flat side of the package was made to confirm acceptable performance in that orientation. In that case, support of a hard vacuum by the containment seal was used as a substitute for a complete helium leakage rate test.

Therefore, in all, a total of two NCT, 0.3-m free drops, eight HAC, 9-m free drops, and more than ten puncture drop tests were performed on the half-scale test unit, as summarized in Table A1. Although the leakage rate tests performed on the half-scale package were not necessarily representative of the performance of a full-scale package, it is significant that the package was leaktight in each case. Since the prior and current configurations are quite similar, the results of the prior tests are used to guide the choice of certification test orientations for the current configuration.

4.0 INITIAL TEST CONDITIONS

4.1 Internal Pressure

Since internal pressure has the effect of increasing containment boundary stress, the CSA will be pressurized (at ambient temperature) to an internal pressure of 172 kPa (25 psig), equal to the design pressure. Since resistance to puncture is not significantly affected by internal pressure, internal pressure is optional for the puncture tests. Since the pressure is only an initial condition, monitoring the pressure will be optional.

4.2 Temperature

The maximum free drop impact is important in the evaluation of containment integrity. This corresponds to the minimum temperature condition of -29 °C (-20 °F), due to the increase in crush strength of the energy-absorbing materials (polyurethane foam) with decreasing temperature. Consequently, for those free drop orientations in which the impact may be bounding, the CTU will be tested at a foam material temperature of -29 °C (-20 °F) or less.

The maximum free drop deformation is important in the evaluation of the ability of the overpack structures to absorb all of the drop energy prior to "lock-up" and to protect the elastomer containment seals during the hypothetical fire. Consequently, for those free drop orientations in which maximum crush deformation may be bounding, the CTU will be tested at ambient temperature. The measured crush deformations will subsequently be extrapolated to their maximum values, corresponding to NCT warm temperatures, using analysis.

The puncture resistance of the TRUPACT-III package is primarily a function of the properties of the stainless steel puncture-resistant plates, and these properties do not vary significantly with temperature. Therefore, all puncture drops are performed at ambient temperature.

4.3 Test Facilities and Instrumentation

The certification drop and puncture testing will be conducted using a drop pad having a weight of at least 10 times the weight of the CTU, or at least 250,000 kg (550,000 lbs). The top of the pad will be covered by an embedded steel plate of adequate thickness such that the drop pad will represent an essentially unyielding surface. The puncture bar will be a 150 mm (6 inch) diameter bar of mild steel, mounted perpendicular to the drop pad, and having an edge radius not exceeding 6 mm (0. 25 inches). The bar will be reinforced by gussets at its base and welded securely to the pad. The length of the bar

will permit the bar to do maximum damage before the package becomes supported by the drop pad, but it will be at least 20 cm (8 inches) long. More than one length of bar may be used. Puncture bars will not be reinforced beyond what is necessary to provide rigidity at the baseplate joint.

CTU temperature will be measured by means of thermocouples embedded in the foam. As a minimum, the region of foam expected to undergo crush deformation will be monitored.

The primary means of recording the results of the certification testing will be physical measurements and observations of the CTU before and after testing. Each free drop impact will be recorded using accelerometers. Since puncture drop impacts are not governing for impact, puncture drops will not be instrumented. As a minimum, conventional speed video cameras and still photography will record each event. High speed filming may also be used.

4.4 Certification Test Unit Configuration

The CTU is an essentially prototypic representation of a full-scale TRUPACT-III package. Any differences between the CTU and a production TRUPACT-III package are discussed and justified below.

1. The CTU utilizes no thread inserts on the closure bolts, which are optional. But since the production unit inserts are made of hardened alloy steel, the holding strength of the closure bolts is conservatively less in the absence of thread inserts. Therefore, this difference is conservative.
2. To help ensure bounding free drop impacts, the crush strength of the polyurethane foam in the regions of impact for the cold temperature free drops will be biased toward the high side of the standard tolerance band. A crush strength up to half of the tolerance band above the maximum value may also be accepted in these regions. Conversely, foam in the regions of impact of the maximum crush free drops will be biased toward the lower half of the standard tolerance band. A crush strength up to half of the tolerance band below the minimum value may also be accepted in these regions.
3. To ensure conservative leakage rate measurement of the CTU containment seal, the compression of the seal will be modified to be less than or equal to the minimum compression of the production unit (PU) seal. Since the leakage rate tests will occur at ambient temperature, the reduction in compression due to a package temperature of -29 °C is also taken into account. The maximum compression, γ, of the CTU seal will therefore be:

$$\gamma_{\text{CTU-MAX}} \leq [\gamma_{\text{PU-MIN}} - \Delta\gamma_{\text{Reduction for cold temperature}}]$$

4. Special vent and test ports will be added to the side of the CTU that do not occur on the production unit. These added ports are located away from structural damage areas, and do not affect the behavior of the CTU. They provide for leak testing the CTU without removal of the overpack cover.
5. No rails, pallets, or energy absorbing dunnage are included in the test unit. Absence of these structures is conservative, since their beneficial capacity to absorb impact energy will not be present. Their weight, however, will be included in the simulated payload.
6. Several minor package features may be omitted from the CTU: Package nameplate, tamper-indicating device, pressure relief valve on the overpack cover, rubber bumper strips in the

payload cavity, and external paint. Lack of these items will not affect the outcome of the certification tests.

7. The CTU payload, which accounts for the weight of the roller floor, the pallet, the waste container, and the waste, will weigh a minimum of 5,125 kg (11,300 lb). This value will be adjusted upward using additional material, as necessary, to ensure that the total weight of the CTU is at least equal to the maximum gross weight of the TRUPACT-III package of 25,000 kg (55,125 lb).

Except for these differences, the CTU will be in full compliance with the SAR drawings of the TRUPACT-III package. Prior to any certification testing, the CTU will undergo all relevant acceptance tests and fabrication data approval, and will receive a certificate of compliance with all drawing and specification requirements.

4.5 Simulated Payload

The payload of the TRUPACT-III package will consist of essentially the same waste stream as is transported in the TRUPACT-II and HalfPACT packages, with the difference that the waste containers will consist primarily of rectangular steel boxes (Other traditional waste containers, such as drums, may also be used). The boxes will rest on a relatively thin pallet, which will rest, in turn, on a roller floor attached to the lower side of the package interior. Since the structures of the box, pallet, and roller floor may provide some beneficial energy absorption during impact, a payload of loose metal bars will be used in the certification tests for conservatism. The bars will be of a material, stiffness, and length to ensure negligible internal energy absorption during impact, and an interaction with the containment boundary of bounding severity. The bars may be bound in small groups for convenience. As stated above, the aggregate weight of the bars will equal, as a minimum, the maximum weight of the contents of the TRUPACT-III package (roller floor, pallet, waste containers, and waste), but will be adjusted upward, if necessary, to ensure that the CTU weight is at least equal to the maximum gross weight of the TRUPACT-III package.

5.0 IDENTIFICATION OF WORST-CASE TEST ORIENTATIONS

In order to determine the worst-case drop and puncture orientations, an exhaustive consideration of all uniquely different free and puncture drop orientations was made. Each uniquely different orientation was evaluated to determine if bounding forces, stresses, strains, or damage to the sealing area would occur. From that review, a subset of bounding events was generated. As will be seen, very few free or puncture drops can affect the containment criteria in regions remote from the lid O-ring seals. Instead, the majority of events that can affect the containment criterion are focused on the lid sealing region.

Note: In the following, an edge is defined as a line where two sides meet at a right angle. A corner is defined as a point where three sides meet.

The raw set of all possible drops and punctures is grouped in summary form as follows:

I. Free Drops on the Ends (12)

A. Flat end (package vertical). Total of two drops. Although the overpack construction is essentially the same at each end, the CSA construction is somewhat different.

B. Near vertical on each edge. Total of four drops, since each end has only two unique edges.

C. C.g.-over-end edges. Total of four drops, since each end has only two unique edges.

D. C.g.-over-each corner. Total of two drops, since there is only one unique corner per end.

II. Free Drops on the Sides (9)

A. Flat (package horizontal). Total of two drops, since there are only two unique sides.

B. On side edges (package horizontal). Total of one drop, since all four side-edges are identical.

C. Slapdown on flat side, lid primary. Total of two drops, since there are two unique sides.

D. Slapdown on flat side, lid secondary. Total of two drops, since there are two unique sides.

E. Slapdown on side-edge, lid primary. Total of one drop, since all side-edges are identical.

F. Slapdown on side-edge, lid secondary. Total of one drop, since all side-edges are identical.

III. Puncture Drops (through c.g. unless stated otherwise) (8)

A. Puncture on the side drop damage.

B. Puncture on the overpack cover.

C. Puncture on the overpack cover center.

D. Puncture on the closed end center.

E. Puncture on the overpack cover joint (front side).

F. Puncture on the overpack cover joint (top/bottom).

G. Puncture on the c.g.-over-corner drop damage.

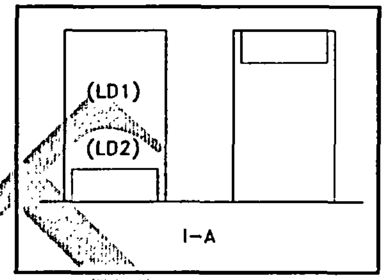
H. Puncture on the side-edge drop damage.

A discussion of each category follows. Each drop or puncture orientation is evaluated to determine whether it is unique and whether it places bounding loads on the package, or represents bounding damage to the sealing area that could affect thermal performance. The result of all of these evaluations is summarized in Section 6.0. Note: in the following small figures, a number in parentheses (e.g., LD1), indicates that the test orientation will be performed as summarized in Table 1.

As noted in Section 3.1 and discussed further in the following paragraphs, many orientations have been tested in prior certification test programs using the half scale test article. The results of these tests provide a database of information which is used to guide the choice of bounding tests to be performed on the full-scale CTU. Table A1 shows the extent of previous testing using the half-scale article.

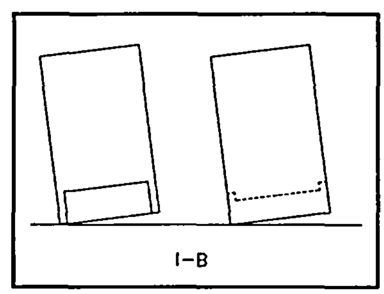
5.1 Free Drops on the Ends

I-A. Flat End Free Drops (Package Vertical). The overpack construction at each end is essentially identical, and therefore the impacts are considered identical at each end. However, the CSA structure is different at each end: the closed end has 8 mm plates and is continuously connected to the sides, whereas the lid has 12 mm plates and is connected to the sides by closure bolts. Consequently, the closed end structure is a plate with essentially fixed edges and the lid is a plate which is essentially simply supported. Under a distributed load (such as the payload in a vertical drop), the bending stress at the edges of the closed end is about 50% greater than at the center of the lid. However, the lid flange may rotate and affect the ability of the containment seal to remain leaktight. From these considerations, it is not obvious whether the lid down or closed end down drops would present a bounding case. The lid end down orientation places the greatest loads on the lid structure and on the closure, potentially deforming the sealing area; the closed end down potentially creates bounding stresses in the containment boundary.

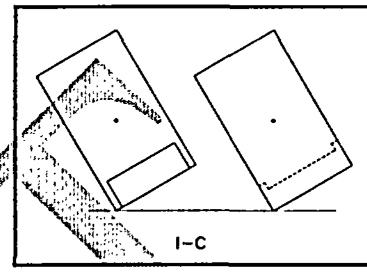


During the certification testing of the TN-Gemini in France in 1994, the half-scale test article was dropped 9 m on the closed end with an equivalent full scale impact of 179g. No damage or deformation was noted in the closed end region of the CSA after this (and several subsequent) tests. Since the construction of the CSA of the TRUPACT-III package is essentially identical to that of the TN-Gemini, and since the expected maximum end drop impact of the TRUPACT-III package (as redesigned) is essentially the same at 188g, it is not necessary to retest this orientation. The robust nature of the TRUPACT-III package closed end has been adequately demonstrated in the half scale test. Since the lid end down orientation places the greatest loads on the lid structure and closure, the TRUPACT-III package will be tested in a lid-down orientation under maximum-impact (cold) conditions.

I-B. Near-Vertical End Free Drops. The impact magnitude drops off rapidly with the off-vertical angle of impact, and consequently the near-vertical impact will be much less than the vertical impact. This was demonstrated in the half scale test at Sandia in 2003. In the bottom-down end drop, the impact occurred at an angle of approximately 6° - 7° from the vertical, with an equivalent full scale impact of 109g. An equivalent impact under the same conditions on the opposite end of the article, in which the orientation was essentially perfectly vertical, was 327g, or three times higher. Also, since the lid is supported by the overpack cover only in the vicinity of its four corners, it will still be left unsupported near the middle of its four sides, even in a pure vertical drop. Finite element analyses have shown that the deflections of the lid will be greatest at the middle of the sides. In other words, whether the package orientation is vertical or near vertical, the most vulnerable areas of the closure and sealing structures are unsupported by impact absorbing structures. Therefore, since the forces driving seal area deformation fall off rapidly, even for small off-

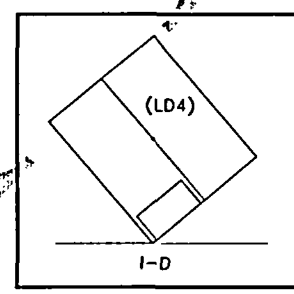


vertical angles, but the vulnerability of the closure structures are essentially unchanged, the near-vertical end free drops are not bounding and do not need to be performed.



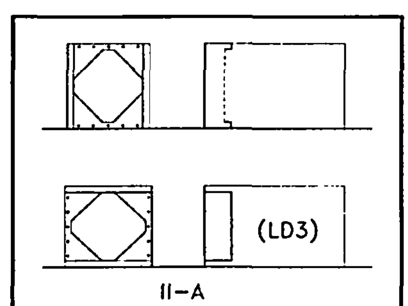
I-C. C.g.-Over-End Edges. These orientations provide neither maximum component loading nor maximum seal area stress, as discussed in the section above. Further, the thermally-relevant crush in the seal area is less than the softer corner case discussed below.

If dropped on one edge of the cover, an "overturning moment" might be applied to the cover attachments. However, since the cover is relatively soft, allowing the crush to be localized, there is no risk of sufficient load transfer to the opposite side so as to fail the cover attachment bolts. This condition was demonstrated in the certification testing in France in 1994, in which a 9-m, c.g.-over-lid-end edge test was performed, without any apparent challenge to the cover attachment. Therefore, this free drop is not bounding and does not need to be performed.

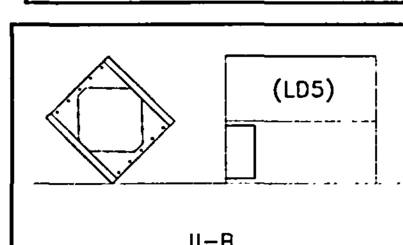


I-D. C.g.-Over-Corner. This orientation produces the greatest total deformation, since the crushed area is relatively small compared to other orientations. All four corners are essentially identical on each end. For this reason, a drop on the closed end corner would likely produce the same overall deformation as a drop on the lid end corner. However, since there is no thermal shield structure on the closed end, a drop on the closed end could not readily supply information about the performance of the thermal shield under these conditions. In addition, if puncture drop is performed on top of this damage, the presence of the lid end cover joint may be significant. Therefore, the TRUPACT-III package will be tested in the lid-down, c.g.-over-corner orientation at ambient temperature. More deformation would occur at maximum NCT temperature, but it can be shown that the additional deformation caused by the accumulation of damage of this drop with the vertical end drop (I-A) is conservatively greater. Therefore, no analytical adjustment of the deformation needs to be made.

5.2 Free Drops on the Sides



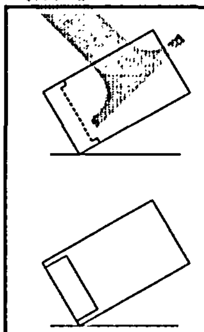
II-A. Flat Side Free Drops. In these orientations (upper side/bottom side or left side/right side), the wall against the ground is squeezed by the payload, and the upper flat wall is in bending under its own weight. Due to the large size of the impact surface, impact loads in the side drop are bounding. Slapdown is not governing as discussed below. Therefore, the TRUPACT-III package will be dropped in the side orientation, with the impact surface horizontal, under maximum-impact (cold) conditions.



II-B. Side-Edge Free Drop. In this orientation, the package is horizontal, with one side edge down and the opposite side edge directly above (c.g. over edge). This is a single orientation since all four edges are alike. A side-edge drop was performed during

the certification of the TN-Gemini in France in 1994, and resulted in no deformation of the CSA (i.e., diagonal measurements of the CSA interior showed no change from the impact.) The greatest risk in this orientation is to the thermal shield, since excessive deformation along the crush axis could damage the shield or the thermal insulation behind it. Therefore, the TRUPACT-III package will be tested in the side-edge orientation. To obtain maximum deformation, the test will be performed at ambient temperatures with results extrapolated to maximum temperatures by analysis.

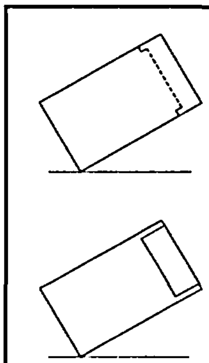
II-C. Slapdown on Flat Sides, Lid Primary. There are two orientations, one with the cheeks[1] vertical (normal transport orientation), and one with the cheeks horizontal. The cheeks vertical case would presumably put greater loads on dislodging the cover, but the cheeks horizontal case would be overall a larger load since it represents a slightly larger impact area. Since the difference in side length is less than 6%, the distinction between sides can be ignored, and the orientation of interest is the short side down, with the cover vertical. In this orientation, the apparent loads on cover attachments are greatest.



II–C

However, the loads on the cover attachments are not important. Based on the fact that the impact limiting cover is "soft" (see I-C above), the primary impact of the cover will not place any important "moment" loads on the cover. The initial impact is in a direction to drive the cover on, but there will be little moment transfer to the top row of attachment bolts. The loads on the lid itself are bounded in the axial direction by the vertical drop (I-B) and in the lateral direction by the flat side drop (II-A). Therefore, this free drop is not bounding and does not need to be performed.

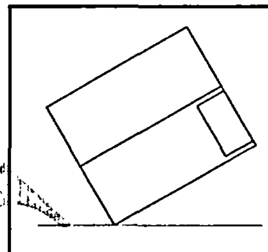
II-D. Slapdown on Flat Sides, Lid Secondary. Again, there are two orientations, one with the cheeks vertical, and one with the cheeks horizontal. However, since the secondary impact angle is nearly horizontal, very little crush damage is experienced either way, as demonstrated by the half scale slapdown drop performed at Sandia in 2003. In that test, the crush deformation at the secondary end of the package was only about 50 mm (in equivalent full scale), or less than 2% of the total height of the package. The secondary impact of the package, perpendicular to the ground, was 325g, and decreased rapidly going toward the package center. As a result of changes to the overpack energy absorbing materials, and to the fact that the package is shorter than previously, the slapdown secondary impact is expected to fall well below 325g, and will now be bounded by the flat side drop. Since the flat side drop impact will bound the slapdown secondary impact, and since the flat side orientation is essentially the same as the slapdown secondary orientation (i.e., essentially horizontal), the flat side drop will bound the impact conditions of the slapdown drop, particularly at the closure lid, and the slapdown free drop test does not need to be performed.



II–D

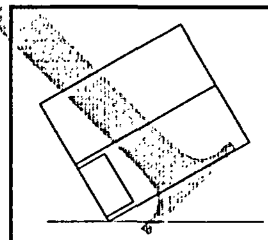
[1] The cheeks are the structures that extend from the package on either side of the lid. The cover fits between the two cheeks.

II-E. Slapdown on Side Edge, Lid Primary. Since the side edge drop is softer in impact than the flat side drop, the impact in this case is not governing. Further, since the c.g. over corner end drop puts all of the package energy into a single corner, but the diagonal slapdown divides the energy between corners, the damage to the corner will be governed by the c.g. over corner drop (I-D). Therefore, this free drop is not bounding and does not need to be performed.



II–F

II-F. Slapdown on Side Edge, Lid Secondary. For the same reasons stated above, neither the crush deformations nor the impacts will be governing, and consequently, this free drop does not need to be performed.



II–E

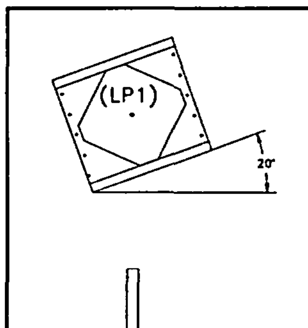
5.3 Puncture Drops

A brief summary of the TRUPACT-III package design as related to puncture will facilitate the discussions which follow.

- Puncture-resistant plates are located within the overpack on the four long sides and on the octagonal end panels, which are designed to prevent puncture perforation of the containment boundary. Puncture-resistant plates are also present on the ends, outside the octagon panels.
- A stainless steel thermal shield, enclosing thick thermal insulation, envelops the elastomeric seal region around the closure lid joint, and covers the vent port.
- At the closure end, the cheeks provide protection to the elastomeric containment seal. The cheeks must have sufficient strength to resist significant deformation from puncture bar impact.
- The top and bottom joints between the overpack cover and the body overpack must resist significant penetration by the puncture bar, since they are in the vicinity of the elastomeric containment seal.
- Significant crush damage can occur in the c.g. over corner drop and in the side-edge drop. The structure must be capable of resisting significant additional damage from the puncture bar in the vicinity of the elastomeric containment seal.

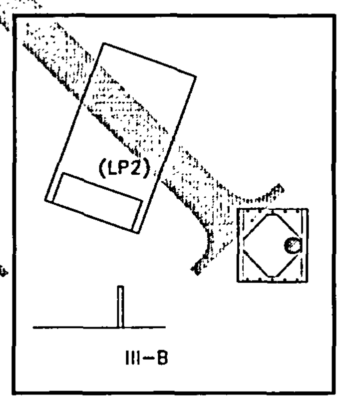
Puncture orientations are considered through the package c.g. unless a different orientation would be more damaging.

III-A. Puncture on the Side. In this orientation, the bar axis is aimed through the c.g. of the package, and is oriented at 70° to the package surface (or 20° off the normal). The puncture will take place on the side of the package which experienced the flat side free drop impact, although since the structural damage is expected to be negligible, particularly in terms of its effect on puncture resistance, any of the

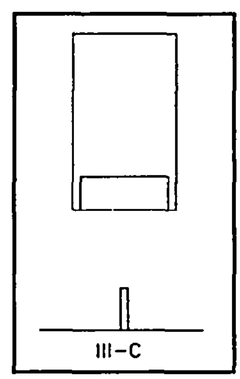


III–A

long sides may be used for this test. The angle was chosen based on the results of a series of standard puncture tests at different orientations using the half scale test article. This puncture was originally performed in France in 1994 using a test article which did not feature the puncture-resistant plates, and it was not successful. The test was soon repeated after installation of the puncture-resistant plates, and was successful. (Note: the French testing was at an angle of 30°.) To clearly demonstrate the puncture resistance of the TRUPACT-III package, this puncture drop will be performed again.

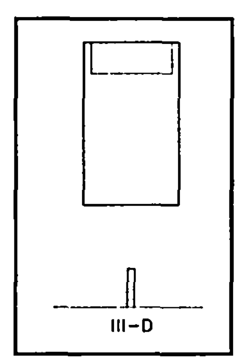


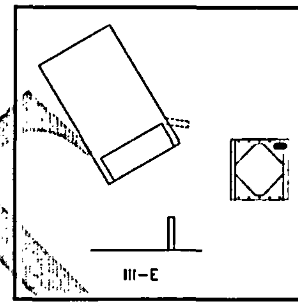
III-B. Puncture on the Overpack Cover. In this orientation, the bar axis is aimed through the c.g. of the package, at an angle which is oblique as possible considering the geometry of the overpack cover octagonal recess. The impact point will be on the recessed octagonal surface. This puncture will challenge the puncture-resistant plate near its edge. It also takes place in the vicinity of the closure bolts and elastomeric containment seal. A puncture test was performed on the closed end of the half scale test article at Sandia in 2003, and caused slight damage to the outer plate of the CSA. Since then, the puncture-resistant plates on both ends have been increased in thickness by 50%. The engineering test performed in 2005 demonstrated a good margin of safety on perforation of the containment boundary and on degradation of the elastomeric seals. To clearly demonstrate the puncture resistance of the TRUPACT-III package, this puncture drop will be performed again (in this instance, on the closure lid end.)



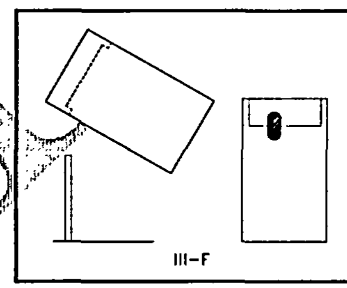
III-C. Puncture on the Overpack Cover Center. In this orientation, the puncture bar impacts the center of the overpack cover through the package c.g. Since the bar axis is not oblique to the surface, this test is not considered as severe as the oblique impact described in III-B above. Furthermore, this test was performed during certification testing of the TN-Gemini in France in 1994. In that case, the overpack cover did not have a puncture-resistant plate, and the bar penetrated through the thickness of the octagonal region and left a depression in the lid outer sheet. However, the inside (containment boundary) sheet of the lid showed only an insignificant deformation, and the test unit was leaktight. Due to the addition of the puncture-resistant plate to the overpack cover, and to the somewhat lighter weight of the TRUPACT-III package, the margin of safety demonstrated in prior testing will be increased, and this puncture drop does not need to be performed.

III-D. Puncture on the Closed end Center. This orientation is similar to the one discussed above (III-C), except that the location is the center of the closed end octagonal area instead of the overpack cover. For the same reasons given in paragraph III-C, this puncture drop does not need to be performed.

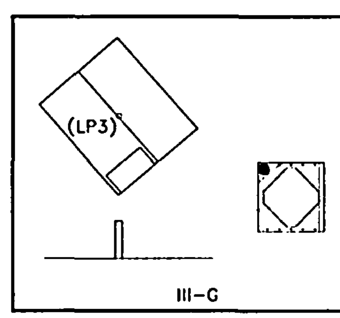




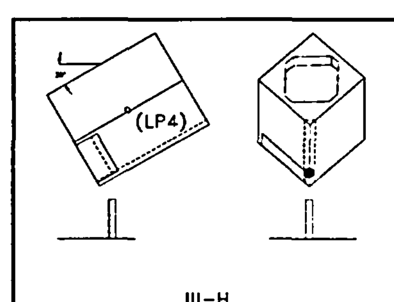
III-E. Puncture on the Overpack Cover Joint (Front Side). The purpose of this puncture is to damage the thermal protection of the lid elastomeric containment seal by compromising the integrity of the cheek structure. It is at an angle away from the package, in an attempt to tear the cheek away from the package, exposing the edge of the lid. Although the bar axis will not be through the c.g., the damage will be done before the package can rotate very far. The angle between the bar and package is not extremely critical, and is approximately 45°. The impact point is essentially on the ISO corner fitting, since this structure is a fairly rigid region and will help to distribute the load to the cantilever root of the cheek. This test was performed on the half-scale test unit in 2003. The puncture bar struck as planned, but essentially no damage resulted. This demonstrated the effective resistance of the TRUPACT-III package to this mode of failure, and this puncture drop does not need to be performed.



III-F. Puncture on the Overpack Cover Joint (Top/Bottom). The purpose of this puncture is to damage the thermal protection of the lid containment seal by opening up the joint between the overpack cover and body along the top or bottom of the package. This is an oblique impact on the overpack cover joint, aimed toward the package end so as to penetrate as deeply as possible. The bar axis is aimed away from the c.g., since damage is likely to be greater if the bar force is towards the nearby package end. If the bar were aimed toward the package c.g., the structure is more resistant to puncture due to the presence of the puncture-resistant plate, and any damage that occurred would tend to be further from the lid sealing area. The oblique angle of the bar to the package is not critical, and an angle of 30° is chosen. This test was performed on the half scale test unit in 2003. The resulting damage was not bounding compared to the c.g.-over-corner free drop and puncture combined damage. For this reason, this puncture drop does not need to be performed.



III-G. Puncture on the C.G.-over-Corner Drop Damage. The damage from the c.g. over corner free drop is expected to result in the greatest crush distance, as described above (I-D). Therefore, the puncture on this damage might penetrate deeper than any other orientation. This puncture drop will be performed.



III-H. Puncture on the Side-Edge Drop Damage. The side-edge drop damage will result in deformation in the vicinity of the thermal shield (see II-B). Puncture on this damage might interfere with the function of the thermal shield. The puncture bar should attack the package in a manner to cause the greatest compromise

of the thermal shield. A puncture bar alignment through the package c.g. would be too steep (45°) for maximum damage to occur. If the bar impacted the package at a lesser angle, more damage would likely occur even though it was not through the c.g. For this reason, the package axis will be oriented at 30° to the horizontal for the worst case ripping effect on the damaged area opposite the thermal shield. This puncture drop will be performed.

6.0 SUMMARY OF CERTIFICATION TESTS

Based on the discussions in Section 5.0, the planned certification tests for the TRUPACT-III package are summarized in Table 1. Free drops are depicted in Figure 1 and punctures in Figure 2.

6.1 Test Sequence and Damage Accumulation

The sequence of testing is first free drops, then puncture drop tests. The order of tests has been chosen to minimize the intermingling of damage from one test to the next, and to minimize interference with post test measurements. A total of one, 0.3-m free drop, four, 9-m free drops, and four, 1-m puncture tests are planned.

The test will begin with the 0.3-m (NCT) and 9-m (HAC) free drops, oriented vertically, striking flat on the lid end. The temperature will be cold, and the damage is expected to be minimal (about 50 mm). These drops will be followed by the flat side drop, also at cold temperature. Although some interaction will occur with the damage from the vertical free drops, it will be negligible, considering the extent of damage (about 50 mm) compared to the length of the package side (4,288 mm).

The c.g. over corner free drop will follow next, and will occur at ambient temperature on a corner which is opposite from the side drop. Since the vertical free drop affects the entire lid-end face, some interaction between the vertical drop damage and the c.g. over corner damage will occur. Since the purpose of the c.g. over corner test is to generate the maximum deformation, the combination with the vertical free drop damage will be conservative. Crush estimates show that the increased crush distance will be relatively small (somewhat less than 50 mm) and the maximum strain (crush distance divided by original thickness of foam between the outside corner and the thermal shield corner) remains acceptable. Since the extra crush due to damage accumulation is greater than the increase in crush which would occur if the c.g. over corner drop were performed at maximum NCT hot temperature (an amount less than 25 mm), no adjustment for hot temperature needs to be made.

The final free drop is the side-edge at ambient temperature, which will occur on an edge unaffected by either the side drop or the c.g.-over-corner drop. As for the side drop, the minor amount of interaction with the vertical end drop will be negligible. In contrast to the c.g.-over-corner drop, an adjustment for NCT hot temperature will be made.

With one exception, the four punctures will occur on prior free drop damage as shown in Table 1, in accordance with 10 CFR §71.73(a). The puncture on the overpack cover takes place within the octagonal recess, where no free drop damage can occur.

6.2 Measurements

As stated in Section 1, the licensing basis for the TRUPACT-III package will be primarily a demonstration by test. The measurements which must be taken to support this demonstration are based on the acceptance criteria given in Section 7.0, and are:

- Helium Leakage Rate Testing. A helium leakage rate test of the containment seal, per ANSI N14.5, will be performed after closing the package and prior to opening the package. At intermediate points in the test program, helium leakage rate testing or the application of a hard vacuum may be employed as a check. At the conclusion of all testing, the vent/sampling port and containment boundary will also be helium leakage rate tested.
- Measurements of the crushed overpack. Detailed photographs or hand sketches of the free drop and puncture damage, including length of any split weld seams, will be created.
- Accelerations of the free drop impacts. Several accelerometers will be arranged redundantly on the package surface. Signals will be recorded and filtered to capture the rigid body deceleration of impact. The filtering frequency will be chosen after analysis of the raw data.
- Temperature. For the cold tests, the temperature of several locations of the CTU will be monitored to ensure that relevant portions of the impact limiting materials are at or below the required temperature. The temperature will also be monitored in the ambient temperature tests to ensure the package has been allowed to warm as much as possible prior to the two ambient free drop tests.

Other measurements which may be taken include closure bolt length bolt residual torque, lid lateral location, and internal cavity dimensions.

Table 1 - Summary of Certification Tests

No. ①	Test Description	Discussed in ¶ No.: ②	Purpose of Test & Expected Damage
LD1	Vertical, Lid Down, NCT	I-A	Test closure attachments and seal area. Minimal crush on end face. Little or no effect on subsequent HAC drops.
LD2	Vertical, Lid Down, HAC	I-A	Test closure attachments and seal area. Little or no permanent deformation of the lid, approximately 50 mm of crush on the end face.
LD3	Flat Side	II-A	Test closure attachments, seal area, lid lateral support, and unsupported wall under maximum impact conditions. Crush damage will be minimal.
LD4	C.g.-over-Corner, Lid Down	I-D	Quantifies possible maximum crush for use in thermal analysis. Crush will reduce distance between corner and internal thermal shield. Accumulation of damage with LD2 is not excessively conservative.
LD5	Side-Edge	II-B	Quantifies possible maximum crush for use in thermal analysis. Crush will reduce distance between edge and internal thermal shield.
LP1	Puncture on Side Damage	III-A	Test ability of puncture-resistant design to resist penetration at worst-case oblique angle.
LP2	Puncture on Overpack Cover	III-B	Test ability of puncture-resistant design to resist penetration on package end.
LP3	Puncture on c.g.-over-Corner Damage	III-G	Quantifies possible maximum accumulation of free drop and puncture damage.
LP4	Puncture on Side-Edge Damage	III-H	Quantifies possible maximum accumulation of free drop and puncture damage.

Notes:

1. All drops (LDx) are from 9 m, except LD1 which is from 0.3 m, and all punctures (LPx) are from 1 meter.
2. Non-bounding tests are omitted from this table, and are discussed in paragraph nos. I-B, I-C, II-C, II-D, II-E, II-F, III-C, III-D, III-E, and III-F.
3. Tests LD1, LD2, and LD3 are at cold temperature. All other tests are at ambient temperature.

7.0 ACCEPTANCE CRITERIA

The following are the acceptance criteria for certification testing of the TRUPACT-III package:

1. The containment boundary shall remain leak tight per ANSI N14.5, as demonstrated by post-test leakage rate testing. As a minimum, the containment boundary shall be leaktight at the conclusion of all free and puncture drop testing; intermediate leakage rate tests may also be performed.
2. Damage to the package as a result of free drop or puncture events shall not be of such a magnitude that the maximum temperature limit of the containment seals or of the CSA material would be exceeded in a subsequent fire. This will be determined using thermal analysis that includes a representation of the worst-case combination of free drop and puncture damage.

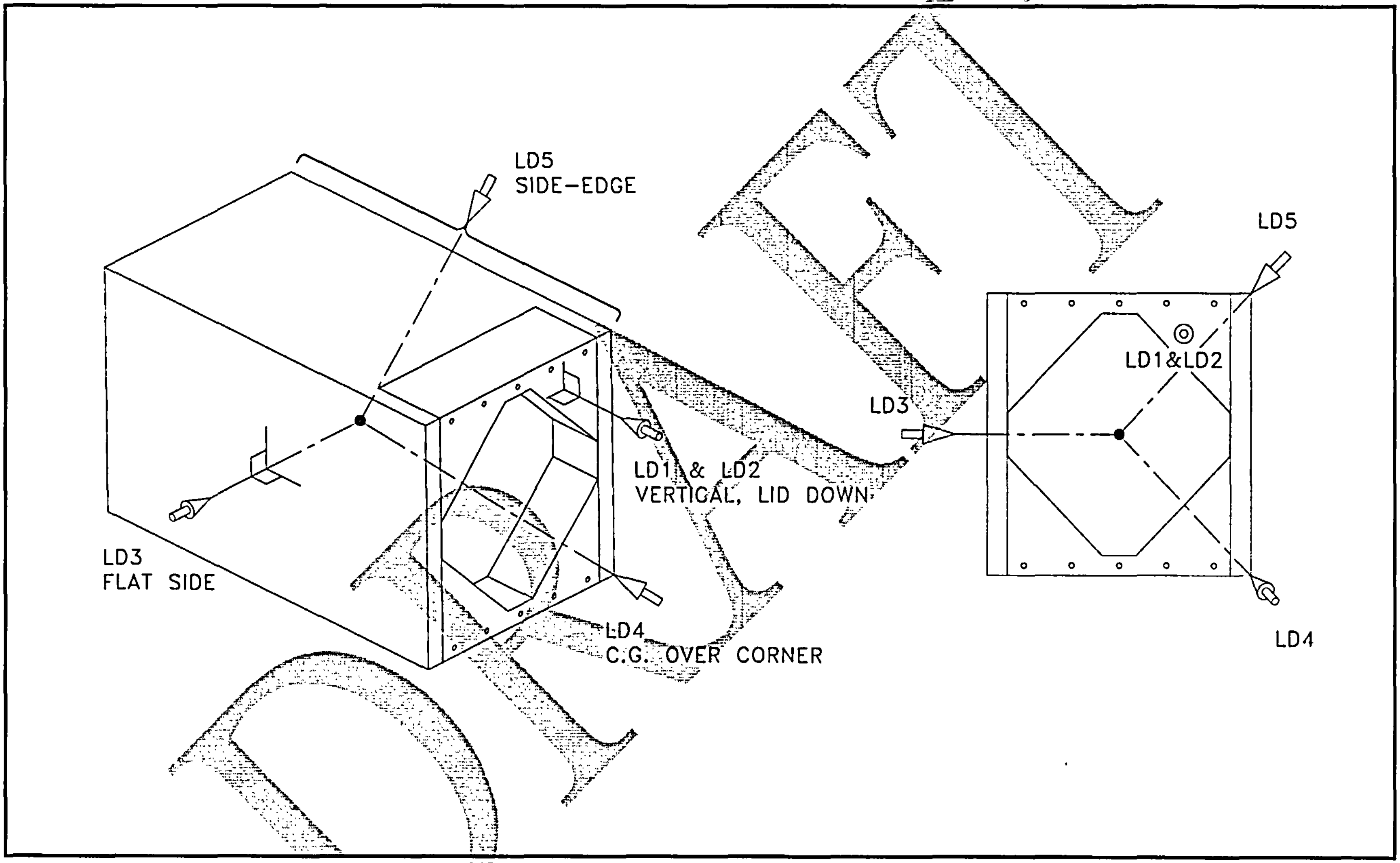


Figure 1 - TRUPACT-III package Free Drop Orientations

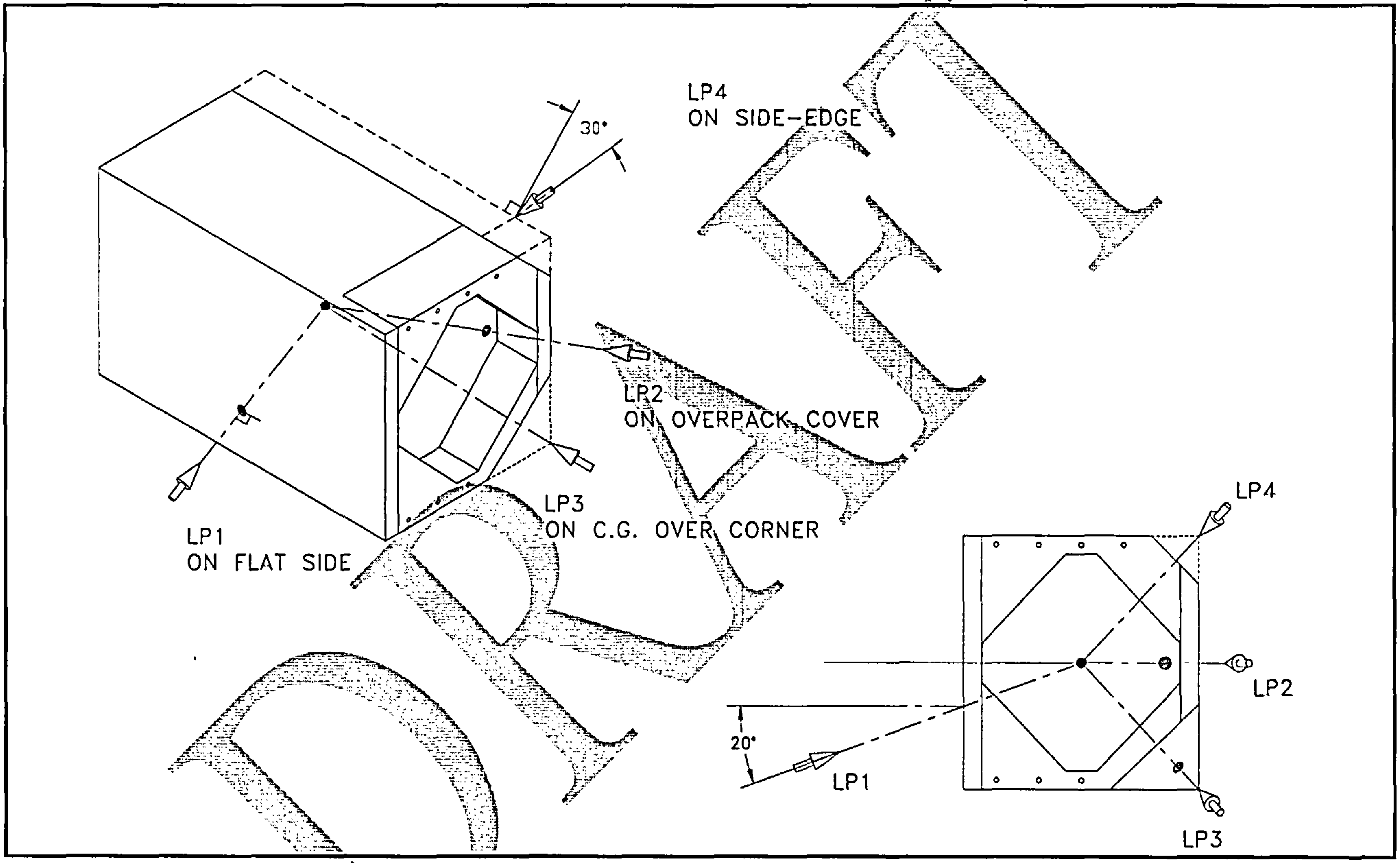


Figure 2 - TRUPACT-III Package Puncture Drop Orientations

APPENDIX

Table of Prior Free and Puncture Drop Tests on the TRUPACT-III package

Table A1 - Summary of Prior Tests on the Half-Scale Test Unit

No. ①	Test Description	Test Type	Discussed in ¶ No.:	Results
Tests in France, 1994 (TN-Gemini)				
A1	C.g.-Over-Lid Edge (NCT)	Free Drop	I-C	Demonstrated integrity of cover attachments
A4	C.g.-Over-Lid Edge (HAC)	Free Drop	I-C	Demonstrated integrity of cover attachments
A6	Horizontal on Side Edge	Free Drop	II-B	Demonstrated integrity of containment
F2	Vertical, Closed End Down	Free Drop	I-A	Demonstrated integrity of containment
C7	C.g.-Over-Corner	Free Drop	I-D	Quantified maximum crush
F3	Center of Overpack Cover (0°)	Puncture	III-C	Demonstrated integrity of closure and lid
F5	Side Wall Oblique	Puncture	III-A	Not successful – puncture-resistant design added
F9	Side Wall Oblique	Puncture	III-A	Demonstrated adequacy of puncture-resistant design
C8	Cover Joint	Puncture	III-E	Demonstrated adequacy of cover thickness
Tests in USA, 2003 (TRUPACT-III package)				
FD1	Vertical, Closed End Down	Free Drop	I-A	Demonstrated integrity of containment
FD2	Vertical, Lid Down, NCT	Free Drop	I-A	Demonstrated integrity of closure and lid
FD3	Vertical, Lid Down, HAC	Free Drop	I-A	Demonstrated integrity of closure and lid
FD4	Slapdown on Flat Side, Lid Second'y	Free Drop	II-D	Demonstrated integrity of cover and closure
P1	Cover Near Lid Bolts	Puncture	III-B	Demonstrated need for puncture-resistant design in cover
P2	Cover Joint (Front Side)	Puncture	III-E	Demonstrated integrity of cheek design
P3	Cover Joint (Top Side)	Puncture	III-F	Demonstrated integrity of cover joint design

Table A1, continued				
P4	Closed End Oblique (19°)	Puncture	N/A	Demonstrated need for improvement of puncture-resistant design on ends
Engineering Tests in 2005				
FD5	Flat Side	Free Drop	II-A	Demonstrated integrity of containment structure
P5	Closed End Oblique (19°)	Puncture	N/A	Demonstrated adequacy of revised puncture-resistant design
P6	Side Wall Oblique (several angles)	Puncture	III-A	Demonstrated worst-case oblique attack angle

Notes:

1. Drop designations shown are those of the French SAR, the March 2004 NRC Docket 71-9305 SAR, and Engineering Test Report, respectively.