ASTM D 4169 - 16
TRANSPORT SIMULATION TEST

The test-procedure for a single packaging or a combination of pallet-packaging’s

Written by Michel Magendans
TRANSPORT SIMULATION TEST

• History and background
  • A “world-wide accepted” packaging standard is the: ASTM (American Society for Testing and Materials) international D 4169 Performance of shipping containers and systems.
  • Therefore Sebert Trillingstechniek, an accredited ISO 17025 test laboratory, use this ASTM standard as the guideline to specify the test-procedure for the packaging’s.

• Test Procedure
  • Within this chapter the test-procedure for a single-packaging and a combination of pallet-packaging’s will be determined and clarified. As stated before the ASTM standard D4169 is the one to start from.
  • Section 8 describes the complete procedure to achieve an uniform basis of evaluating, in a laboratory, the ability of shipping units to withstand the distribution environment.
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• Define Shipping Units
  • Describe shipping unit in terms of size, weight, and form of construction.
  • Determine of the shipping unit will be manually or mechanical handled

• Determine Acceptance Criteria
  • In many cases, the acceptance criteria can be the following:
    • Criterion 1 – Product is damage-free
    • Criterion 2 – Package is intact
    • Criterion 3 – Both

• Select Distribution Cycle (DC)
  • Out of table 1 of the ASTM D 4169, DC should be chosen which correlates to the projected distribution. This is categorized from DC 1 till DC 18
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• Select Distribution Cycle (DC)

Environmental Factors

Temperature, Humidity, compression

Vibration, Humidity, Temperature

Shock, Humidity, Free Fall EMC

Vibration, Bump, Temp change, Humidity, ESD

Environments during operational use

Life Cycle Phase

Storage

Transport

Handling

Transport

Use

Example of environmental factors within each environmental phase

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• Select Distribution Cycle (DC)

Out of the test schedule the complete test-procedure is derived:
• **Schedule A** *(Handling Impact Test)* is described in section 10.
  • *In this case (see paragraph 8.1) a single packaging or a combination of pallet packaging’s are supposed to be handled manual or mechanical from the distribution centre to the “end customer”.*
  • **Schedule D or E** *(Random Vibration Test)* is described in section 12.2.
    • *Underneath section 12.1 the random test is considered to be the preferred one. Recommended intensities and durations are given in 12.4.*
    • *If only one single packaging is available and you will simulate a pallet packaging then it is recommended to put a concentrated load as calculated in section 11.4. This test is also called Schedule C Vehicle Stacking plus vibration.*
  • **See Annex A** below in this presentation for more information about the changed truck vibration profile and how to accelerate the test time of the simulations.
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- **Select Distribution Cycle (DC)**
  - **Schedule F (Sine Vibration Test)** is described in section 13.1.
    - *This test determine the ability of the shipping unit to withstand the repetitive shocks occurring during transportation of loose loads. For example whipping/slamming of a boat or a bad way.*
  - **Schedule J (Concentrated Impact Test)** is described in section 17.1.
    - *This test provides a simulation of anticipated low level concentrated impacts as received by packages during sorting operations and in transit.*
  - **Schedule A (Handling Impact Test)** a repeated as described before
    - *Only for the single packaging is the last impact of the last manual handling sequence different. The impact should be made at twice the specified height. This is the final drop in the sequence (not an additional drop). The drop should be in the impact orientation most likely for a drop to occur, usually the largest face or the bottom. For distribution cycles where any drop orientation is possible, this drop should be in the most critical or damage-prone orientation, as define in test Method D 5276.*
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- Select Samples for Test
  - Tests specimens consist of representative samples of complete shipping units, including actual contents. Products with blemishes or minor defects may be used if the defective component is not to be studied by the test and if the defect is documented in the report.

- Condition samples
  - Normal condition to 23 +/- 1°C, 50 +/- 2% relative humidity with a (pre)conditioning of 72h is recommended for samples which are sensitive for temperature and humidity.
  - It is also possible to carry out the (vibration) test under -40°C till +70°C, in combination with till 95% humidity.

- Perform tests
  - Perform test in accordance with a test plan (see below Write a Test Plan) and following up the special instructions for each test schedule.
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• Evaluate Results
  • Evaluate results to determine if the shipping units meet the acceptance criteria as defined.

• Document Test Results
  • Document test results by reporting each step.

• Monitor shipments (important)
  • When possible, obtain feedback by monitoring shipments of the container that was tested to ensure that the type and quantity of damage obtained by the laboratory testing correlates with the damage that occurs in the distribution cycle. This information is very useful for the planning of subsequent tests of similar shipping containers.
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• Write Test Plan

Yes

Single Packaging

No

Western Europe

Yes

Test plan A

No

Western Europe

Yes

Test plan B

No

Western Europe

No

Test plan C1/C2

Test plan D1

Test Plan with Test Schedule Sequence

Additional tests

Test (Assurance) Levels Definition

S2T: FOR ALL YOUR TRANSPORT TEST

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## Test Plan A: Single packaging outside of Western Europe (Truck & Air Simulation)

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Procedure</th>
<th>Test Method</th>
<th>Test Level</th>
<th>Number of impacts</th>
<th>Direction</th>
<th>Test duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Free Fall Drop Test [FFDT]</td>
<td>Simulation of loading a box for storage, handling or sorting</td>
<td>§10.2.3 – Schedule A – Manual Handling – 1\textsuperscript{st} sequence</td>
<td>ASTM D 5276</td>
<td>assurance level I</td>
<td>6 drops on different sides, edges and corners</td>
<td>30 min vertical, 15 min transversal, 15 min longitudinal</td>
<td>60 minutes</td>
</tr>
<tr>
<td>B: Random Truck Vibration Test [RTVT]</td>
<td>Simulation of Vibration behaviour of a air/leaf spring truck</td>
<td>§12.4 – Schedule E – Vehicle Vibration</td>
<td>ASTM D 4728 (Fig X 1.1 truck)</td>
<td>assurance level II</td>
<td>30 min vertical, 15 min transversal, 15 min longitudinal</td>
<td>60 minutes</td>
<td></td>
</tr>
<tr>
<td>C: Random Air Vibration Test [RTVT]</td>
<td>Simulation of Vibration behaviour of a small air plane</td>
<td>§12.4 – Schedule E – Vehicle Vibration</td>
<td>ASTM D 4728 (Fig X 1.1 Air)</td>
<td>II</td>
<td>120 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D: Free Fall Drop Test [FFDT]</td>
<td>Simulation of loading a box for storage, handling or sorting</td>
<td>§10.2.3 – Schedule A – Manual Handling – 2\textsuperscript{nd} sequence</td>
<td>ASTM D 5276</td>
<td>assurance level I</td>
<td>6 drops on different sides, edges and corners</td>
<td>60 minutes</td>
<td></td>
</tr>
<tr>
<td>E: Concentrated Impact Test [CIT]</td>
<td>Simulation of Small point impacts caused by grading</td>
<td>§17.1 - Schedule J – Concentrated impact</td>
<td>ASTM D 6344</td>
<td>3 drops on 0,8 meter in vertical direction</td>
<td>60 minutes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**TRANSPORT SIMULATION TEST**

**Test Plan B: Single packaging inside of Western Europe (Truck Simulation)**

<table>
<thead>
<tr>
<th>Test A: Free Fall Drop Test [FFDT]</th>
<th>Test C: Random Air Vibration Test [RTVT]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation of: loading a box for storage, handling or sorting</td>
<td>Simulation of: Vibration behaviour of a small air plane</td>
</tr>
<tr>
<td>Test Method: ASTM D 5276</td>
<td>Test Method: ASTM D 4728 (Fig X 1.1 Air)</td>
</tr>
<tr>
<td>Test Level: assurance level II</td>
<td>Level: II</td>
</tr>
<tr>
<td>Number of impacts: 6 drops on different sides, edges and corners</td>
<td>Test duration: 60 minutes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test B: Random Truck Vibration Test [RTVT]</th>
<th>Test D: Free Fall Drop Test [FFDT]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation of: Vibration behaviour of a leaf spring truck</td>
<td>Simulation of: loading a box for storage, handling or sorting</td>
</tr>
<tr>
<td>Test Method: ASTM D 4728</td>
<td>Test Method: ASTM D 5276</td>
</tr>
<tr>
<td>Cycle: 40 minutes low → 15 minutes medium → 5 minutes high</td>
<td>Test Level: assurance level II (1 drop on each rib, total 4 drops)</td>
</tr>
<tr>
<td>Direction: 1 cycle vertical, 1 cycle transversal, 1 cycle longitudinal</td>
<td>Number of impacts: 6 drops on different sides, edges and corners</td>
</tr>
<tr>
<td>Test duration: 2 cycles (total 120 min) is 1100 km simulation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test E: Concentrated Impact Test [CIT]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation of: Small point impacts caused by grading</td>
</tr>
<tr>
<td>Procedure: §17.1 - Schedule J – Concentrated impact</td>
</tr>
<tr>
<td>Test Method: ASTM D 6344</td>
</tr>
<tr>
<td>Test Level: 1 drop on 0.8 meter in vertical direction</td>
</tr>
</tbody>
</table>
## TRANSPORT SIMULATION TEST

### Test Plan C1: Pallet packaging Inside of Western Europe (Truck Simulation)

<table>
<thead>
<tr>
<th>Test A: Side Impact Test [SIT]</th>
<th>Test D: Rotational Flat Drop Test [RFDT]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simulation of</strong></td>
<td>Simulation of</td>
</tr>
<tr>
<td>loading a pallet unit for storage and handling or sorting</td>
<td>unloading a pallet unit for storage, handling or sorting</td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
<td>Procedure</td>
</tr>
<tr>
<td>§10.3.2.2 – Schedule A – Mechanical Handling</td>
<td>§10.3.2.3 – Schedule A – Mechanical Handling</td>
</tr>
<tr>
<td><strong>Test Method</strong></td>
<td>Test Method</td>
</tr>
<tr>
<td>ASTM D 880 (Method B)</td>
<td>ASTM D 6179 (Method C)</td>
</tr>
<tr>
<td><strong>Test Level</strong></td>
<td>Test Level</td>
</tr>
<tr>
<td>assurance level II (1 impact on long and short side)</td>
<td>assurance level III (1 impact on two opposites sides)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test B: Rotational Flat Drop Test [RFDT]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simulation of</strong></td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
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<tr>
<td><strong>Test Method</strong></td>
</tr>
<tr>
<td><strong>Test Level</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test C: Random truck Vibration Test [RTVT]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simulation of</strong></td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
</tr>
<tr>
<td><strong>Test Method</strong></td>
</tr>
<tr>
<td><strong>Cycle</strong></td>
</tr>
<tr>
<td><strong>Test duration</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test E: Side Impact Test Plus [SITP]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simulation of</strong></td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
</tr>
<tr>
<td><strong>Test Method</strong></td>
</tr>
<tr>
<td><strong>Test Level</strong></td>
</tr>
</tbody>
</table>
### Test Plan C2: Pallet packaging Inside of Western Europe (Truck Simulation)

#### Test A: Random truck Vibration Test [RTVT]
- **Simulation of:** Vibration behaviour of a leaf spring truck
- **Procedure:** §12.4 – Schedule E – Vehicle Vibration
- **Test Method:** ASTM D 4728
- **Cycle:** 40 minutes low → 15 minutes medium → 5 minutes high
- **Test duration:** 3 cycles (total 180 min) is 1600 km simulation

#### Test B: Side Impact Test [SIT]
- **Simulation of:** Unloading a pallet unit for storage and handling or sorting
- **Procedure:** §10.3.2.2 – Schedule A – Mechanical Handling
- **Test Method:** ASTM D 880 (Method B)
- **Test Level:** Assurance level II (1 impact on each side, total 4 impacts)

#### Test C: Rotational Flat Drop Test [RFDT]
- **Simulation of:** (un)loading a pallet unit for storage, handling or sorting
- **Procedure:** §10.3.2.3 – Schedule A – Mechanical Handling
- **Test Method:** ASTM D 6179 (Method C)
- **Test Level:** Assurance level II (1 drop on each rib, total 4 drops)
### Test A: Side Impact Test [SIT]
- **Simulation of**: loading a pallet unit for storage and handling or sorting
- **Procedure**: §10.3.2.2 – Schedule A – Mechanical Handling
- **Test Method**: ASTM D 880 (Method B)
- **Test Level**: assurance level I (1 impact on each side, total 1 sides)

### Test B: Rotational Flat Drop Test [RFDT]
- **Simulation of**: loading a pallet unit for storage, handling or sorting
- **Procedure**: §10.3.2.3 – Schedule A – Mechanical Handling
- **Test Method**: ASTM D 6179 (Method C)
- **Test Level**: assurance level II (1 impact on long and short side)

### Test C: Random Truck Vibration Test [RTVT]
- **Simulation of**: Vibration behaviour of a leaf spring truck
- **Procedure**: §12.4 – Schedule E – Vehicle Vibration
- **Test Method**: ASTM D 4728
- **Cycle**: 40 minutes low → 15 minutes medium → 5 minutes high
- **Test duration**: 2 cycles (total 120 min) is 1100 km simulation

### Test D: Random Air Vibration Test [RTVT]
- **Simulation of**: Vibration behaviour of a small air plane
- **Procedure**: §12.4 – Schedule E – Vehicle Vibration
- **Test Method**: ASTM D 4728 (Fig X 1.1 Air)
- **Level**: II
- **Test duration**: 60 minutes

### Test E: Rotational Flat Drop Test [RFDT]
- **Simulation of**: unloading a pallet unit for storage, handling or sorting
- **Procedure**: §10.3.2.3 – Schedule A – Mechanical Handling
- **Test Method**: ASTM D 6179 (Method C)
- **Test Level**: assurance level II (1 impact on two opposites sides)

### Test F: Side Impact Test Plus [SITP]
- **Simulation of**: unloading a pallet unit for storage and handling or sorting
- **Procedure**: §10.3.2.2 – Schedule A – Mechanical Handling
- **Test Method**: ASTM D 880 (Method B)
- **Test Level**: assurance level II (1 impact on two opposites sides)
Additional Tests

• Climate Test

• It is possible to carry out a vibration test in combination with low temp (-40°C) in our laboratory or high climate 45°C with 95% RH (Hong Kong)
Additional Tests

• Under pressure test
  • It is possible to carry out a low pressure vibration test in combination with climate conditions in our ISO 17025 accredited laboratory.
Additional information

• Annex A
  • Changing of the truck random vibration profile
    • June 2016 the ASTM D 4169-14 is replaced into ASTM D 4169-16.
    • The biggest change in this version is paragraph 12.4 a reduction of the stress intensity level of the truck vibration test profile.
    • The truck assurance level I-III is replaced into Low => High
    • Test time is changed into Cycle testing (1 hour ~ 525 km)

• Accelerated testing
  • increase your test time is more realistic than increase the vibration intensity levels
Changing of the ASTM D 4169 truck test profiles and test times

ASTM D 4169 versie 14 vs 16

Power Spectrum Density [g²/Hz]

Frequentie [Hz]

ASTM Level I (versie 14)
ASTM High (versie 16)

W

m² ~ g rms
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Truck environmental simulation stress (freq. range 1-200Hz)

1 cycle = 60 minutes
(40 min. low + 15 min. medium + 5 min. high level)
Simulates ±525 km

400 Minutes = ±525 km
5 min. = 50 km
15 min. = 210 km
40 min. = 265 km
525 km

Based on an average truck speed of 80km/h

Root Mean Square (RMS)
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• Is it possible to increase the test level for a faster vibration simulation test?  YES, but........careful

Example;
hatching from an egg
Takes normally
21 day’s on 35°C

we cannot wait 21 day’s

What happens when we increase the temperature???
Too high temperature (acceleration) gives another result!!!

It is more realistic to increase the test time, than increase the vibration intensity levels.

The following formula can be used for calculation of the test time

\[
\text{Test time} = \text{Material constant} \times \frac{\text{Test level}}{\text{Transport level}}
\]

We prefer cycle testing from low → high level, because this happens with a real transport environmental
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What is the added value?
Sebert Trillingstechniek is accredited by the Dutch Accreditation Council (RvA). The RvA is part of European Accreditation (EA). As the Recognized Regional Cooperation Body, EA is affiliated with ILAC. The RvA is a full member of ILAC:
http://ilac.org/ilacmembership/

If tests are carried out by an ISO 17025-accredited test laboratory, ILAC recognises and accepts accredited tests worldwide, which is not possible if the tests are carried out by an ISO 9001 or ISTA test laboratory. The technical aspect of the ISO/IEC 17025 standard relates to the use of qualified and experienced staff. All test equipment has been calibrated and checked in accordance with the ISO/IEC 17025 standard. Validated methods are also used for testing, recording and reporting of results. This ensures that the tests, obtained in an independent, professional and objective manner, are extremely reliable. You also have certainty about the quality of the test results.
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Referenced documents

*Six step method from Lansmont Corporation*

*Environmental Engineering Handbook from Swedish Environmental Engineering Society*

*Transportation Stresses from Committee of European Environmental Engineering Societies Department of Defense Test Method Standard MIL-STD 810 F*

*ASTM Standards*

- D4169 Standard Practice for performance Testing of Shipping Containers and systems
- D996 Standard Terminology of Packaging and Distribution Environments
- D5276 Standard Test Method for Drop Test of Loaded Containers by Free Fall
- D880 Standard Test Method for Impact Testing for Shipping Containers and Systems
- D6179 Standard Test Methods for Rough Handling of Unitized Loads and Large Shipping Cases and Crates
- D999 Standard Methods for Vibration Testing of Shipping Containers
- D4728 Standard Test Method for Random Vibration Testing of Shipping Containers
- D6344 Standard Test Method for Concentrated Impacts to Transport Packages