Package Design: Design Testing and Analysis I

Quality Assurance Requirements for Mechanical Test Campaigns of Packagings

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(1) Intention, objective, requirement
(2) Test specimen and facility
(3) Test program
(4) Test procedures and performance
(5) QA Measurements
(6) Summary
Quality assurance (QA) refers to the engineering activities implemented in a quality system so that requirements for a product or service will be fulfilled. *(www.ASM.org)*

QA is the systematic measurement, comparison with a standard, monitoring of processes and an associated feedback loop that confers error prevention. *(WIKIPEDIA)*

Quality assurance systems emphasize catching defects before they get into the final product.
Objective and purpose of mechanical testing in relation to quality assurance interacting fields

- Design verification
- Quantification of stresses and deformations
- Verification of calculations (methods, models)
- Identification of construction weak points

- Verification of manufacturing and inspection methods (with test specimen first)
- Quantification of leakage rates

- Safety demonstration
- Public acceptance improvement

Aims of Drop Tests

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Motivation & Requirements

Methods of safety proof in accordance with the regulations for shipping of radioactive material

Regulations for the Safe Transport of Radioactive Material (IAEA Specific Safety Requirements No. SSR-6)

Test for Packages (SSR-6, §713-737)

Compliance with the requirements by any of the following methods or a combination thereof (SSR-6, §701)

(a) Experimental testing of small-scale or full-scale packaging model or prototype; using dummy inventory

(b) Reference to previous satisfactory tests of similar nature

(c) Performance of tests with models of appropriate scale and with respect to engineering experience

(d) Calculations or reasoned arguments with generally agreed methods and parameters, reasonably conservative
Preconditions for conduction of mechanical tests

Complete development of the conceptual design and layout up to the detail mechanical design and dimensioning.

Design and manufacturing of the test specimen under consideration of preliminary technical examination, quality-assuring controls and acceptance by independent experts.

Approved drop test specification with test positions and sequences to meet the most-damaging-criteria for all safety-relevant package components, maximum and minimum temperatures, etc. also with consideration of the subsequent thermal test, and if so based on adequate reasoning of modeling and its validation.
Experimental Testing of RAM Packages (BAM)

BAM 3.3 Division
Safety of Transport Containers
- Experimental testing of containers
- Design assessment of packages for transport of radioactive material
- Special form radioactive material; Special issues of transp. packages

BAM 3.3 Sect.
Experimental Testing of Containers
Tests
Test Data & Report

BfS
Federal Office for Radiat. Protection
(Application for Approval)

BAM 3.4 Division
Safety of Storage Containers
- Evaluation of interim storage containers
- Safety evaluation of disposal containers; Decommissioning; Dismantling
- Numerical container analysis

Application
Purchase Order
Customer
Accreditation Certificate DAP-PL-2614.17 since July 2004

IAEA TS-R-1, NCT
722, 725(a) : Free Drop Test
724, 725(b) : Penetration Test

IAEA TS-R-1, ACT
727 (a-c)
Free Drop Tests I, II, III

DIN/BS EN 13185
Leak testing – Tracer gas method

BAM: Quality Management Manual (MH)

Annex to the Accreditation Certificate:
Accredited testing methods within mechanical testing of packages and dangerous goods
Typical mechanical and thermal test facilities

- **Drop test facility with test hall (BAM TTS):** 200,000 kg / 30 m
- **Impact tester:** 50g-20 kg/1m
- **Drop test machine (BAM TTS):** 1,200 kg / 12 m
- **Thermal test stand (BAM TTS):** 200,000 kg
- **Indoor drop test facility (BAM Berlin):** 4,000 kg / 9 m
Check on arrival and start of preparation

- Technical documentation (checked acc. to requirements; non-conformance reports)
- Certificate of conformity
- Certification of testability
- Materials and parts lists
- Technical and as built drawing
- Main geometrical positions and relevant dimensions
- Specific handling and testing equipment

Lid bolts (M42)
Check of PL
Arrival with mounting frame
(1) Test Program

Direct connections

- Concept and aims of safety demonstration
- Testing objectives
- Test program
  - Tests
  - Handling concept
  - Test procedure plans
  - Measurement objectives
    - Measuring methods
    - Measuring points
  - Instrumentation plan

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Aspects and scope of test specifications

Focus of investigations and measuring methods:

**Stress analysis**
- Accelerometers
- Strain gages
- Pressure indicated film

**Deformation analysis**
- Recording: High-speed video, video, foto
- Manual surface shape measurement
- 3-d measurement like tactile or optical fringe projection and photogrammetry

**Integrity analysis**
- Visual inspection
- NDT methods: leakage testing, surface crack testing
- Tightening torque of bolts and screws

Testing procedure and performance:

- Drop test sequences and measuring program
- Test procedure plan
- Sensor instrumentation plan
- Work and testing instructions
- Test equipment
- Handling procedure
- Responsibilities of involved parties
- Time schedule
(3) Test Program

Typical drop test scenarios

- **End-on**
- **Side-on**
- **CG-over-corner**
- **Slap-down (First impact: Lower)**
- **Slap-down (First impact: Upper)**

1m-penetration (Horizontal)

1m-penetration (Vertical)

Legend

- Closure
- Lower Impact Limiter
- Upper Impact Limiter

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(4) Test Program

Documents for approval

- Drop Test Program
- Test Procedure Plan
- Instrumentation Plan
- Handling Concept

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Specific handling and testing equipment

- Safety and risk evaluation on test site
- Certificates and statements concerning mechanical design, operating and functions
- Consideration of Machinery Directive (MD/EC)
Drop test setup

Hook of 200-t hoist

Release system

Nylon slings

Measuring cables

Cooling box

High-speed cameras

9-m vertical drop
End on position
Specimen temp. -40°C

IAEA Target

Calibration of drop height by laser rangefinder

Drop height: 9 m

CG over corner 9-m drop

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**Instrumentation Plan**

**Strain and deceleration measurement**

- **Sensor information:**
  - Specification: no., code, type
  - Designation of the manufacturer
  - Coordinates for installation: axial and angular position
  - Measuring plane: sector, radius, zone
  - Measuring direction
  - Active at which mechanical test

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Cable and connection terminal acc. to SOP

Ref.: Lab. QMM / Standard Operation Procedures (SOP):
Recording of electronic measuring data / Measurement of strains with strain gages / Measurement of accelerations
QA – Measurement Instrumentation

Documentation of electronic measurement

- Electronic and visual inspections of all sensors
- Check of all electric installation points and cable connections,
- Report of inspection with photo documentation

Protocol of setting and check-up of data acquisition system

Quality control:
- Coding, numbering, type
- Tags biunique
- Application position
- Electric resistance checks of sensors, cables, connection points
Calibration and testing

- Installation and preparative measures
- Basic calibration of the Helium leak detector by means of testleak
- Base alignment (internally) of He leak detector
- Measurement of He background
- Measurement of the leakage rate
- Data recording and documentation

Usual design leakage rates:
- Storage: $1 \times 10^{-8}$ Pa·m³/s
- Transport: $1 \times 10^{-4}$ bis $1 \times 10^{-6}$ Pa·m³/s
Measurement Uncertainties

**Expanded Uncertainty** $U_k$

$$U_k = k \sqrt{\sum_{i=1}^{n} G_i (c_i u_i)^2}$$

$$c_i = \frac{\partial f(x_1, \ldots, x_i)}{\partial x_i} \quad f(x_1, \ldots, x_i)$$

$k$ ... coverage factor

$U_i$ ... standard uncertainty

$G_i$ ... weighting coefficient

$c_i$ ... sensitivity coefficient

**Main influences on $U$**

**Acceleration**
- Tolerance of the accelerometer’s sensitivity
- Amplitude linearity
- Signal conditioning, etc.

**Strain**
- Tolerance of the strain gage factor
- Signal conditioning, etc.

**Leakage Rate**
- Testleak (He-4 gas volume flow)

**Typical values of expanded Measurement Uncertainty**

- Strain measurement: $U_{0.95} = 3 \%$
- Deceleration: $U_{0.95} = 8 \%$
- Standard Leakage Rate: $U_{0.95} = 5 \%$
Test Procedures

Test preparation and performance

Example of drop test preparation in compliance with the test program:

- Drop angle (75°)
- Temperature (80°C)
- Drop height (9 m)
Summary

BAM has established, operates and maintains an effective quality management system at its own responsibility, and for the performance of mechanical test campaigns designed to ensure that the applied test methods meet international accepted quality requirements.

A consistently high quality and reliability of mechanical design tests, as an integral part of design approval procedure for RAM packages can only be achieved if the quality requirements for manufacture and testing of prototypes and test models are clearly defined, the requirements for the quality management system are specified and the quality control methods, including those adopted under the quality management system, are documented accurately.

Based on an excellent QA the investigations and test results can provide **objective evidence** and **high reliability** for the tested specimen or prototype in order to demonstrate sufficient compliance with the requirements.
Thank You for your attention!

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Examples of Container Drop Testing

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