Appendix IV

PACKAGE STOWAGE AND RETENTION DURING TRANSPORT

INTRODUCTION

IV.1. For radioactive packages to be transported safely the Transport Regulations require packages to be restrained from movement within or on the conveyance during the transport operation. The particular requirements of the relevant paragraphs of the Transport Regulations apply in the following ways:

— Paragraph 564: The secure stowage of consignments — this can be ensured by a variety of retention systems (see below).

— Paragraph 607: Each package shall be designed with due consideration being given to its retention systems for each intended mode of transport.

— Paragraph 612: Retention systems which are not part of the package shall not reduce the safety of the package.

— Paragraph 613: The components of the package, its contents and their respective retention systems shall be designed so that the package integrity will not be affected during routine conditions of transport.

— Paragraph 638: The integrity of the package shall not be impaired by the stresses imposed on the package or its attachment points by the tie-downs or other retention systems in either normal or accident transport conditions.

Some aspects relating to these paragraphs are noted in their respective advisory paragraphs in the main text of this publication, but additional detail is contained in this appendix and in Refs [IV.1–IV.36].

IV.2: This appendix provides guidance on considering the effects of the tie-down system loads applied to the package during routine conditions of transport. It describes possible methods for demonstrating compliance with package design requirements. The package will include the tie-down attachment points but not the remainder of the tie-down system. Other components of the tie-down system, which are not part of the package, are addressed by modal and national requirements.

IV.3: The inertial forces that act on the packages during routine conditions of transport (see para 106) may be caused by, for example:

(a) Uneven road or track;

(b) Vibration;

(c) Braking and accelerations;

(d) Direction changes;

(e) Rail shunting (when permitted);
(f) Motions of a ship in heavy seas;

(g) Turbulence in air transport.

The inertial forces that act on the packages during the following circumstances are not considered as routine conditions of transport and are not addressed in this appendix:

(a) Minor impacts with vehicles and obstacles;

(b) Rail shunting (when not permitted);

(c) Very exceptional seas;

(d) Emergency landings in air transport.

IV.4. Package retention systems have to be designed to perform in a predictable manner under all conditions of transport. However, in normal or accident conditions of transport (see para 106), the package is permitted, and may be required as part of the design, to separate from the conveyance by the breakage or designed release of its restraint in order to preserve package integrity.

DEFINITIONS AND GENERAL REMARKS

Fig. IV.1. Tie-down system components
IV.5. Typical retention systems may consist of, among other items, tensile tie-downs or lashings, nets, trunnions on the package secured to bearers on, or flanges bolted to, a transport frame or conveyance, ISO twistlocks, chocks or stillages. Some of these methods of retention may be combined. Figure IV.1 shows examples of components of tie-down systems.

For the purposes of the guidance notes in this appendix, the following definitions of terms used in appendix IV apply:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attachment point</td>
<td>A fitting on the package to which a tie-down member or other retention device is secured.</td>
</tr>
<tr>
<td>Anchor point</td>
<td>A fitting on the conveyance to which a tie-down member or other retention device is secured.</td>
</tr>
<tr>
<td>Chock</td>
<td>A fitting secured to the conveyance for the purpose of resisting horizontal inertial forces.</td>
</tr>
<tr>
<td>Dunnage</td>
<td>Loose material used to protect cargo in a ship’s hold, or padding in a shipping container.</td>
</tr>
<tr>
<td>Retention</td>
<td>The use of dunnage, braces, blocks, tie-downs, nets, flanges, stillages, etc., to prevent package movement within or on a conveyance during transport.</td>
</tr>
<tr>
<td>Stillage</td>
<td>A framework fitted to a conveyance for carrying unsecured packages.</td>
</tr>
<tr>
<td>Stowage</td>
<td>The emplacement within or on a conveyance of a radioactive material package relative to other cargo (both radioactive and non-radioactive).</td>
</tr>
<tr>
<td>Tie-down member</td>
<td>The connecting component (e.g. wire rope, chain or tie-rod) between the attachment and anchor points.</td>
</tr>
<tr>
<td>Tie-down system (or Retention system)</td>
<td>The assembly of an attachment point, an anchor point and a tie-down member.</td>
</tr>
</tbody>
</table>

IV.6. Attachment points are integral parts of the package. All other parts of the retention system such as tie-down members (e.g. lashings, ropes, chains or straps), anchor points, chocks, etc. are not part of the package.

IV.7. The methods of retention should not cause the package to be damaged, or stress components of the package or its attachment points beyond yield, during routine conditions of transport.
IV.8. The consignor and carrier have the responsibility to ensure that the transport of the package is conducted in compliance with the regulatory and transport modal requirements. Persons involved in tie-down should be adequately trained and qualified commensurate with their responsibilities. The design of some tie-down members requires pre-tensionning to avoid slackening during use. In this case, tension in tie-down members should be maintained throughout the journey (e.g. through checking and tightening as required). Potential loosening by vibration during transit should be taken into account. Frequently, larger and heavier packages are secured to the conveyance by means of a dedicated method of retention. Such retention equipment should be consistent with the package design. Operating and handling instructions should be drawn up for the use of any dedicated retention equipment.

IV.9 Training for persons involved in tie-down of packages of radioactive material should be commensurate with their tasks. Typical training programmes should include:

- Legal responsibilities of parties involved (e.g. consignors, carriers) in tie-down operations for the intended modes of transport;
- Specific hazards presented by packages of radioactive material related to tie-down operations (see para 311);
- Forces induced by the transport on the carried packages for the intended modes of transport;
- All requirements for securing packages specific to each intended mode of transport;
- Description of the conveyance and equipment (e.g. anchor points) for the intended modes of transport;
- Methods of retention, associated equipment, design and justification of the tie-down of a package according to the applicable rules;
- Stowage instruction;
- Checks and controls of tie-down equipment, retention and anchor points of the conveyance, the packages and their attachment points prior to the tie-down operations and associated criteria for acceptance;
- Implementation of the different methods of retention and securing (practical application);
- Checking correct stowage before and during carriage.

IV.10 This appendix does not focus on handling loads. However, when an attachment point is used both for lifting and tie-down then the lifting operation loads, including snatch lifting loads (see para 608), should be taken into account in the design.

DEMONSTRATING COMPLIANCE THROUGH ANALYSIS

IV.11. Structural analysis of attachment points under routine conditions of transport should include strength analysis and fatigue analysis of relevant components. If necessary, issues such as brittle fracture and structural stability should be considered. The temperature range of the attachment points under routine conditions of transport should be taken into account.
IV.12. Structural analysis of attachment points can generally be performed by analytical methods, e.g. beam theory, or by numerical methods, e.g. finite element analysis. Numerical methods lead to more detailed stress and strain results for complex structures. The interpretation of these detailed results depends upon the assessment technique (e.g. nominal stress, local stress or stress linearisation). Applicable analysis methods, assessment techniques and design criteria should be acceptable to the relevant competent authorities. Examples of various approaches are given in the Refs [IV.25, 28, 30].

IV.13. Owing to the differences in transport infrastructures and practices, the national competent authorities and the national and international transport modal standards and regulations need to be consulted to confirm the mandatory or recommended package loads, together with any special conditions for transport, which should be used in the design of the packages. These loads are generally specified by acceleration values to represent the package inertial effects for structural analysis, and are usually applied at the package centre of gravity as equivalent quasi-static forces. The load case data may differ according to the type of structural analysis (strength analysis or fatigue analysis).

IV.14. If the design has more than two attachment points then load sharing between them should be carefully considered.

IV.15. For strength analysis the acceleration values representing routine conditions of transport are given in Table IV.1. The values given in Table IV.1 are derived from different national and international standards and guidelines (Refs [IV.1, 2, 3, 6, 8, 14, 27, 29, 31]), using a factor of about 1.25 that increases the confidence that the proposed range of loading will not be exceeded. Use of these acceleration values would generally be good practice but for ground transport in some transit facilities different values may be relevant (e.g. handling of packages at an airport). If a specific design code is used in the analysis, an additional safety factor consistent with the applied code may be required. If no specific design code is used, then a safety factor should be considered and justified in the analysis (see for examples Ref [IV.36]). The forces imposed on the package are determined by multiplying the acceleration values listed in Table IV.1 by the mass of the package and are applied at its center of gravity. The analysis should first consider application of each directional acceleration value separately and then all combinations for each line in Table IV.1 for the relevant transport mode.

**TABLE IV.1. ACCELERATION VALUES FOR STRENGTH ANALYSIS**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Longitudinal</th>
<th>Lateral</th>
<th>Vertical a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>1g</td>
<td>-</td>
<td>1g down ± 0.3g b</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>0.7g</td>
<td>1g down ± 0.3g b</td>
</tr>
<tr>
<td>Rail</td>
<td>1.3g/5g c</td>
<td>0.7g</td>
<td>1g down ± 0.4g</td>
</tr>
<tr>
<td>Sea/water</td>
<td>0.5g</td>
<td>-</td>
<td>1g down ± 1g</td>
</tr>
</tbody>
</table>
The effects of gravity are included.

For packages transported in vehicles lighter than 3,500 kg, higher acceleration values should be considered (Ref [IV.29]). No precise value can presently be proposed due to lack of data.

1.3g should be used if wagons equipped with long-stroke shock-absorbers or if hump and fly shunting operations are explicitly excluded.

IV. 16. It is incumbent upon the package designer to ensure that the package attachment points are designed in compliance with values acceptable to the relevant competent authorities and defined in modal requirements. Table IV.2 provides acceleration values for specific applications. It should be noted that, for some specific package designs, there have already been agreements with many competent authorities and the transport modal organizations that different acceleration values may be used. Table IV.2 details a limited number of such packages and other examples can be found in Refs [IV.1–IV.36], in particular Refs [IV.10–IV.12]. The acceleration values given in Table IV.2 are taken from the appropriate reference and may not be on the same basis as Table IV.1. The source documents should be referred to for clarification.

<table>
<thead>
<tr>
<th>Type of Package</th>
<th>Longitudinal</th>
<th>Lateral</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certified fissile and Type B(U) or Type B(M) packages in the USA [IV.7] All modes</td>
<td>10g</td>
<td>5g</td>
<td>2g</td>
</tr>
<tr>
<td>Carriage of irradiated nuclear fuel, plutonium and high level radioactive waste (INF) on sea going vessels [IV.9] Sea</td>
<td>1.5g</td>
<td>1.5g</td>
<td>1g up, 2g down</td>
</tr>
<tr>
<td>Portable tanks [IV.32, 33] Road, rail, inland water ways and sea</td>
<td>2g</td>
<td>2g</td>
<td>1g up, 2g down</td>
</tr>
</tbody>
</table>

IV.17. In addition to the strength analysis, the package designer should also account for the effects of cyclic loads under routine conditions of transport which could lead to the failure of components of the package. For fatigue analysis, it is preferable to design the attachment point for infinite endurance but, as an alternative, it is also acceptable to determine the fatigue life of the attachment point and to control it in service (e.g. change of component after a defined
service time). A detailed fatigue analysis may not be necessary if the number of load cycles applied to the attachment point do not exceed a threshold specified in the relevant design code. Acceleration values for fatigue analysis [IV.31] imparted by rail wagons are reproduced in Table IV.3. The use of these values is possible if the conditions and criteria of the standard [IV.31] are relevant. Other acceleration values for fatigue analysis for different transport modes can be found in Ref [IV.3]. Cyclic load measurements made during transport are given in Refs [IV.18, 19, 22]. If the data in the reference are not applicable, appropriate measurement data should be provided by the package designer. Acceleration values, number of cycles, allowable stress levels and acceptable design criteria for fatigue assessment should be agreed with the relevant competent authorities. For attachment points that are also used for lifting, the lifting cycles should be included in the fatigue analysis. It should be pointed out that fatigue analysis is not a substitute for inspection and maintenance.

**TABLE IV.3. ACCELERATION VALUES FOR FATIGUE ANALYSIS**

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>Longitudinal</th>
<th>Lateral</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>± 0.3g</td>
<td>± 0.4g</td>
<td>1g down ± 0.3g</td>
</tr>
</tbody>
</table>

IV.18. If the package can be secured on the conveyance in more than one orientation then acceleration values in the appropriate directions should be used in the analysis (e.g. longitudinal could become lateral).

**DEMONSTRATING COMPLIANCE THROUGH TESTING**

IV.19. When using measured data from acceleration sensors, the cut-off frequency should be considered relative to equivalent quasi-static loads. The cut-off frequency should be selected to suit the mass, shape and dimensions of the package and the conveyance under consideration. Experience suggests that, for ground transport of a package with a mass of 100 tonnes, the cut-off frequency should be of the order of 10–20 Hz [IV.8]. For smaller packages with a mass of m tonnes, the cut-off frequency above should be multiplied by \((100/m)^{1/3}\).

**REFERENCES TO APPENDIX IV**

[IV.1] IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units (CTU Code) 2014


[IV.31] DIN EN 12663-2:2010-07 Railway applications-Structural requirements of railway vehicle bodies-Part 2: Freight wagons

[IV.32] European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)

[IV.33] Convention concerning international carriage by Rail (COTIF) – Appendix C - Regulation concerning the International Carriage of Dangerous Goods by Rail (RID) -2015 edition

