Revision of TCSC 1006: Guide to the Securing/Retention of Radioactive Material Payloads and Packages During Transport

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Abstract

The Transport Container Standardisation Committee (TCSC) is a UK nuclear industry group whose main function is to examine the requirements for the safe transport of radioactive material with a view to standardisation and, as appropriate, produce and maintain guidance documentation. The Code of Practice "Guide to the Securing/Retention of Radioactive Material Payloads and Packages During Transport", TCSC 1006 was published in December 2012 following an extensive review lead by Onet Technologies, Peer Review and approval by TCSC committees. The code considers the requirements governing restraint, provides design criteria for various modes of transport and makes recommendations regarding operation and inspection for tie-down systems.

This paper reviews the history of TCSC 1006 as it has developed since it was first published in 1971 and the changes that have occurred since it was last updated in 2003. It summarises the review process that has been undertaken which included a thorough review of the relevant sections of the IAEA regulations and outlines the main changes from the previous edition which are:

- Acceleration factors for all modes of transport which are used to determine the tie-down loadings have been updated

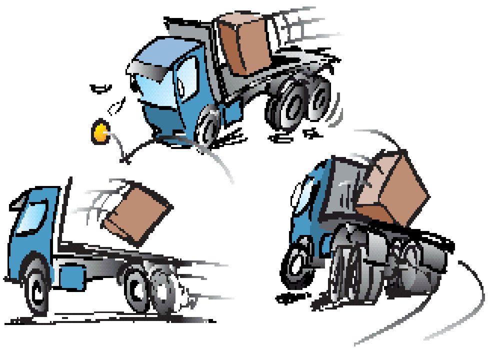
- Additional guidance is provided on the design of specific tie-down systems

- New sections added on payload restraint within a package and special considerations for transport frames

An extensive review of acceleration factors for the various modes of transport was undertaken and recommended values are included in TCSC 1006 as an interpretation of the guidance provided in the IAEA Advisory Material for use in the UK. The paper highlights a number of inconsistencies in the IAEA Regulations and guidance regarding routine and normal conditions of transport when applied to package restraint, particularly the advice that a package is permitted to separate from a conveyance in normal conditions of transport.

1. Introduction

The Transport Container Standardisation Committee (TCSC) is a UK nuclear industry group whose main function is to examine the requirements for the safe transport of radioactive material with a view to standardisation and, as appropriate, produce and maintain guidance documentation.



The movement of a conveyance results in forces which may cause packages to slide or tip over. This can result in damage to the package or other packages or items carried on the conveyance and in the case of radioactive packages may result in unacceptable radiation levels. Packages may fall from a conveyance resulting in loss of or damage to the package, delay and congestion for other conveyances and possibly more serious consequences. Even if a package is contained within a conveyance, a moving load can make a conveyance unstable and result in an accident.

To ensure safe and efficient transportation of radioactive material it is essential to provide adequate means for securing a package containing radioactive material to its conveyance. The revised Code of Practice TCSC 1006, Guide to the Securing/Retention of Radioactive Material Payloads and Packages During Transport, was published in December 2012 following an extensive review lead by Onet Technologies, Peer Review and approval by TCSC committees. The code considers the requirements governing restraint, provides design criteria for various modes of transport and makes recommendations regarding operation and inspection for tie-down systems.

This replaces the previous version published in December 2003. The Code of Practice has been updated to take into account the latest versions of the IAEA and other applicable regulations and guidance and to include additional information on the restraint of the payload (the radioactive contents) within a package and the design of transport frames

The Code of Practice is intended to assist any organisation that is involved in the transport of radioactive material from the transport of small radioactive material packages such as radioactive sources and radiopharmaceuticals to transport in the nuclear power, research and defence industries. It covers all types of packaging from Excepted to Type C as well as unpackaged Low Specific Activity material (LSA-I) and Surface Contaminated Objects (SCO-I) and all modes of transport.

It is written for package designers who have to ensure that a package can be adequately restrained, and for consigners and carriers of radioactive material who have to ensure that suitable restraint systems are used when transporting radioactive material.

TCSC Codes of Practice are available to organisations who are not members of the TCSC by applying for associate membership on the TCSC website www.tcsc.org.uk. There is no charge for associate membership.

2. History

2.1 The Code of Practice was first published in 1971 as Atomic Energy Code of Practice AECP 1006 Securing radioactive material packages to conveyances. It was revised in 1979 to take account of revision of the IAEA Regulations and further revised in 1986.

The Code of Practice was completely revised and re-issued in 1997 as AECP (TCSC) 1006 based on IAEA Safety Series No. 6 1985 Edition, As Amended 1990. An extensive section reviewing in detail IAEA Safety Series No. 6, Regulations for the Safe Transport of Radioactive Material and the associated Advisory material (Safety Series No. 37) and Explanatory Material (Safety Series No. 7) was introduced. A further section reviewed the requirements of the Department of Transport Guide to Applications for Competent Authority Approval applicable to Type B and fissile packages (DTp/RMTD/0001 1992). This issue introduced the concept of “Routine” and “Normal” conditions of transport noting that a tie-down system is permitted to fail under accident conditions of transport but a tie-down system must not fail under Normal Conditions of transport. A series of 5 tables were introduced considering Routine and Normal Conditions with separate requirements for Type B(U) or other Package types. Guidance was provided on the design of tie-down systems in seven broad categories: Trunnion, Corner Ties, Directly bolted, ISO Twistlocks, Strapping, Self retaining and Unrestrained. Formulae were included where appropriate and a series of figures illustrate the various tie-down systems.

The Code of Practice was re-issued in 2003 as TCSC 1006. The main changes from the 1997 issue were to simplify the recommendation regarding the use of acceleration factors in line with the latest IAEA Advisory Material TS-G-1.1 (ST-2) and to refer to the latest issue of the IAEA Regulations TS-R-1 (ST-1, revised) 1996 Edition. Referring to TS-G-1.1 Appendix V, the Code now states that “package retention systems only need to meet the demands of routine conditions of transport, and that under normal or accident conditions of transport the package may separate from the conveyance, and indeed the design or safety requirements may demand that it does”. As discussed later in this paper this seems inappropriate and has now been amended. The methodology was simplified with no distinction between Type B and other package types.

3. Revision Process

3.1 Regulations, Guidance and Standards

The current regulations and guidance specific to the transport of radioactive detail were reviewed in detail. These are:

IAEA SAFETY STANDARDS. REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL. SAFETY REQUIREMENTS No. TS-R-1. 2009 EDITION

IAEA SAFETY STANDARDS. ADVISORY MATERIAL FOR THE IAEA REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL. SAFETY GUIDE No. TS-G-1.1 (Rev. 1) (published 2008)

The references in these documents to Routine and Normal Conditions of transport when applied to tie-down were found to be confusing. Particularly:

TS-G-1.1, paragraph 606.1 states “*The design of a package ... considers only routine conditions of transport*”

TS-G-1.1, paragraph 612.2 states "*In the case of freight containers ... it is essential to design the ... tie-down system of the contents within the container, for the accelerations encountered in routine conditions of transport.*"

TS-R-1, paragraph 636 states that "*Any tie-down attachments on the package shall be so designed that, under normal and accident conditions of transport, the forces in those attachments shall not impair the ability of the package to meet the requirements of these Regulations* with TS-G-1.1 paragraph 636.1 explaining that "*Since the retention system 'shall not impair' the functions of the package under normal and accident loading conditions it may be necessary to design the attachment of the retention system to the package so it would fail first (commonly called the 'weak link').*"

TS-G-1.1, paragraph IV.2 states "*... in normal or accident conditions of transport, the package is permitted, and may be required ... to separate from the conveyance by the breakage or designed release of its restraint in order to preserve the package integrity.*" Since paragraph IV.3 then defines Normal Conditions of Transport as minor impacts with vehicles and obstacles, rail shunting, heavy seas and turbulence or rough landings in air transport, the statement that the package may separate from the conveyance under normal conditions of transport seems inappropriate. Similarly the requirement that the retention need only be suitable for routine conditions of transport is equally inappropriate.

As a TCSC committee member commented: *OK. Unless you don't need to ship abroad and you don't mind the attendant publicity (and resulting litigation) from packages falling off vehicles this is clearly inadequate. Given the clear tiedown requirements laid down by other regulatory bodies, including those for other hazards, and the sensitivity of the public to our industry it would be professionally and morally irresponsible and indefensible to design to this standard.*

This is further confused by the acceleration factors listed in TS-G-1.1 Table IV.1. Paragraph IV.9 states that "*Table IV.1 gives an indication of the magnitude of the acceleration factors which might be used for the design of the package and its retention system for routine conditions of transport. The values given for each mode would be in accordance with most national and international regulations. It is incumbent upon the package designer and user to ensure that the package retention system was designed in compliance with those values specified by the relevant competent authorities and transport modal organizations.*"

This states that the values are for **routine** conditions of transport but they are higher than the values specified in TCSC 1006 Table 2 for normal conditions of transport. Given the confusion over appropriate acceleration factors which are the main feature of TCSC 1006, the specific requirements of various regulations and guidance documents were reviewed.

UN RECOMMENDATIONS ON THE TRANSPORT OF DANGEROUS GOODS (UNRTDG) (Rev. 17 2011)

The UNRTDG forms the basis for all regulations governing the transport of dangerous goods including radioactive materials. Para 7.1.1.8 states "*Packages containing dangerous goods and unpackaged dangerous articles shall be secured by suitable means capable of restraining the goods ... in the cargo transport unit in a manner that will prevent any movement during transport which would change the orientation of the packages or cause them to be damaged.*"

NOTE 2 states "*Additional guidance on the packing of cargo transport units can be found in the IMO/ILO/UNECE Guidelines for Packing Cargo Transport Units (CTUs) contained in the* *supplement to the International Maritime Dangerous Goods Code. Modal and National Code of Practice (such as the Agreement governing the exchange and use of Wagons between Railway Undertakings (RIV2000) Appendix II loading guidelines published by the International Union of Railways (UIC) or the United Kingdom Department for Transport Code of Practice on Safety of Loads on Vehicles) may also be available*".

ADR EUROPEAN AGREEMENT CONCERNING THE INTERNATIONAL CARRIAGE OF DANGEROUS GOODS BY ROAD (2011)

ADR paragraph 7.5.7.1 contains the same requirement with a footnote that guidance on the stowage of dangerous goods can be found in the European Best Practice Guidelines on Cargo Securing for Road Transport published by the European Commission and that other guidance is available from competent authorities and industry bodies.

IMO/ILO/UNECE GUIDELINES FOR PACKING CARGO TRANSPORT UNITS (CTUs) (IMDG CODE SUPPLEMENT Amdt. 35-10 2010)

Section 1.7 of the IMO/ILO/UNECE Guidelines provides guidance on accelerations. The following table provides an example of the accelerations which could arise during transport operations; however, national legislation or recommendations may require the use of other values.

Mode of transport	Forwards	Backwards	Sideways
ROAD	1.0*g*	0.5*g*	0.5*g*
RAILWAY			
Wagons subject to shunting[1]	4.0*g*	4.0*g*	0.5*g* (a)
Combined transport[2]	1.0*g*	1.0*g*	0.5*g* (a)
SEA			
Baltic Sea	0.3*g* (b)	0.3*g* (b)	0.5*g*
North Sea	0.3*g* (c)	0.3*g* (c)	0.7*g*
Unrestricted	0.4*g* (d)	0.4*g* (d)	0.8*g*

[1] The use of specifically equipped rolling stock is advisable (e.g. long shock absorbers, instructions for shunting restrictions).
[2] Combined transport means wagons with containers, swap-bodies, semi-trailers and trucks, and also 'block trains' (UIC and RIV).
The above values should be combined with static gravity force of 1.0*g* acting downwards and a dynamic variation of (a) ± 0.3 *g* (b) ± 0.5 *g* (c) ± 0.7 *g* (d) ± 0.8 *g*

UK DEPARTMENT FOR TRANSPORT CODE OF PRACTICE, SAFETY OF LOADS ON VEHICLES (THIRD EDITION 2002)

The DfT Code is referred to in both TS-G-1.1 and the UNRTDG. It includes acceleration factors for road transport which coincide with those listed in the IMO Guidelines (half the TS-G-1.1 values).

EUROPEAN BEST PRACTICE GUIDELINES ON CARGO SECURING FOR ROAD TRANSPORT (EUROPEAN COMMISSION)

The European Guidelines (referred to in ADR) refer to acceleration factors from IMO/ILO/UNECE Guidelines and European Standard EN 12195-1 "Load restraining on road vehicles", Part 1: "Calculation of lashing forces". The values specified in EN 12195-1:2010 for road, rail and sea transport are generally in line with the IMO code except that only the lower set of values are included for rail transport.

It is apparent from reviewing these various documents that the IMO/ILO/UNECE Guidelines are accepted as being appropriate for the international transport of dangerous goods. The acceleration factors listed are typically lower than those listed in TS-G-1.1 Table IV.1 (which are supposed to apply to routine conditions of transport). While we should of course be particularly cautious in the transport of radioactive materials this does raise the question are the recommendations in TS-G-1.1 excessive when many of the dangerous goods safely transported in accordance with the IMO Guidelines are more hazardous than a lot of radioactive material packages. The selection of accelerations factors used in TCSC 1006 is discussed in section 3.3.

3.2 Review Process

The 2003 issue of TCSC 1006 was subject to a line by line review and a report produced listing proposed changes to the Code and raising points for discussion by TCSC. Following a review by members of the TCSC committee, all comments were collated into the report and further meetings of TCSC members took place to agree the contents of the Code. The revised Code of Practice was approved by the TCSC committee and issued in December 2012.

3.3 TCSC Review

The main decisions were as follows.

The Scope of TCSC 1006 should only cover the UK given the varying requirements of other countries particularly the USA and Japan. The Scope should include unpackaged radioactive materials (LSA-1 and SCO-1).

In reviewing the IAEA documents the Code should be clear that a retention system must restrain a package under Normal Conditions of Transport.

It was decided that reference to Routine and Normal Conditions of Transport should be removed from TCSC 1006 section 3.3 Methodology. Since some TCSC members use the TS-G-1.1 acceleration values for all components of the restraint system it was decided that TCSC 1006 should include the option of using EITHER the acceleration values from TS-G-1.1 with the design stress limited to the yield or proof stress OR lower acceleration values based on international regulations and guidance with the design stress limited to the basic stress (derived from British Standard BS2573) or rated load capacity of the restraint equipment. These acceleration factors were selected on the following basis.

ROAD TRANSPORT
It was agreed that the acceleration factors for road transport should not be changed from the previous issue of TCSC 1006. They coincide with the IMO and DfT Guidelines except that 1g vertical acceleration is added.

RAIL TRANSPORT
It was agreed that the IMO Guidelines which are in line with TS-G-1.1 Table IV.2 radioactive material packages in Europe by rail are appropriate and that separate factors should be included for shunting and combined transport as in the IMO guidelines. It was however decided that 1g vertical and 1g lateral factors should be conservatively adopted.

SEA TRANSPORT
It was agreed that factors based on the IMO Guidelines should be adopted but that the lateral and vertical factors should conservatively be increased from 0.8g to 1.0g. It was further agreed that a separate set of factors should be included for packages subject to the INF Code.

AIR TRANSPORT
It was agreed that existing factors based on the IATA Airport Handling Manual should be retained.

The following acceleration factors are now incorporated in TCSC 1006 Table 2.

Mode of transport	Acceleration factors applied to the package		
	Longitudinal	**Lateral**	**Vertical**
Road	1g	0.5g	1g up, 1g down
Rail			
Wagons subject to shunting	4.0g	1g	1g up, 1g down
Combined transport	1g	1g	1g up, 1g down
Sea			
Subject to INF Code	1.5g	1.5g	1g up, 1g down
Other	1g	1g	1g up, 1g down
Air	1.5g	1.5g	3g up

It is noted that the vertical acceleration factors listed in Table 2 do not include the effects of gravity which should be additionally applied so for road rail and sea transport a vertical acceleration of 1g down due to gravity should be added giving a net upward acceleration of 0 and downward acceleration of 2g.

Acceleration factors from TS-G-1.1 are incorporated in TCSC 1006 Table 4

Mode of transport	Acceleration Factors		
	Longitudinal	**Lateral**	**Vertical**[2]
Road	2g	1g	2g up, 3g down
Rail	5g	2g	2g up, 2g down
Sea	2g	2g	2g up, 2g down
Air	1.5g (9g forward)[1]	1.5g	2g up, 6g down

In reviewing the various types of tie-down system in section 4 of TCSC 1006 a number of changes were agreed which are discussed in section 4 of this paper.

Additional sections addressing payload/contents restraint and Transport Frames were discussed and agreed.

4. Changes to the Code of Practice

The major changes to the Code of Practice TCSC 1006 are as follows.

4.1 The scope has been expanded to include unpackaged radioactive material and payload restraint and it is made clear that the Code of Practice is based on UK requirements which may not be applicable internationally.

4.2 REGULATIONS INFLUENCING THE DESIGN OF TIE-DOWN SYSTEMS

The review of applicable regulations has been expanded to quote the relevant paragraphs from the regulations in full noting particularly that although the regulations and related advisory material state that under normal or accident conditions of transport the package may separate from the conveyance, a load retention or tie-down system must retain the package under Normal Conditions of Transport.

A section referring to the United Nations Recommendations on the Transport of Dangerous Goods (UNRTDG) has been introduced since this forms the basis for all regulations governing the transport of dangerous goods including the transport of radioactive materials.

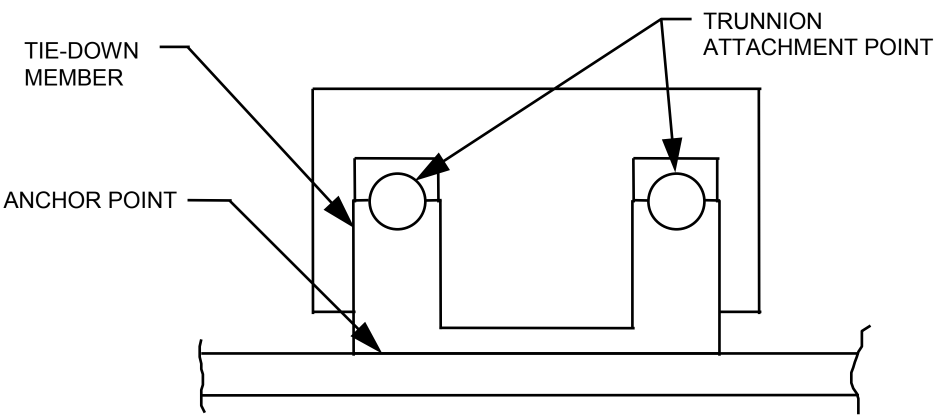
4.3 GENERAL DESIGN PARAMETERS

Guidance on acceleration factors has been revised to remove reference to Routine or Normal Conditions of Transport since this was found to be confusing particularly noting the references to Routine or Normal Conditions of transport in the IAEA Regulations and Advisory Material.

The designer has the option to use the acceleration factors from the IAEA Advisory Material TS-G-1.1 with stresses limited to yield or proof stress levels or to use the lower acceleration factors based on national and international regulations and guidance documents as listed in section 3.3 of this paper but with stresses limited to lower typical design levels.

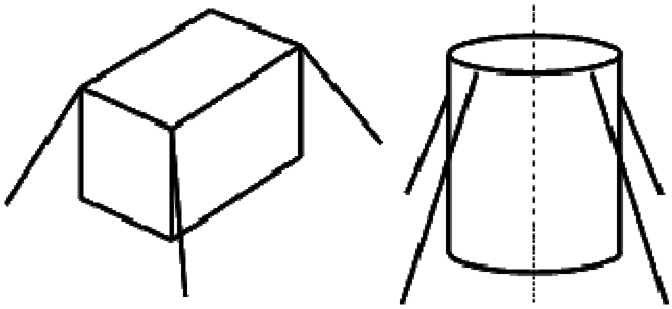
4.4 DESIGN OF SPECIFIC TIE-DOWN SYSTEMS

Trunnion
Trunnions on the package are secured to bearers that are either on a transport frame or form part of the vehicle.



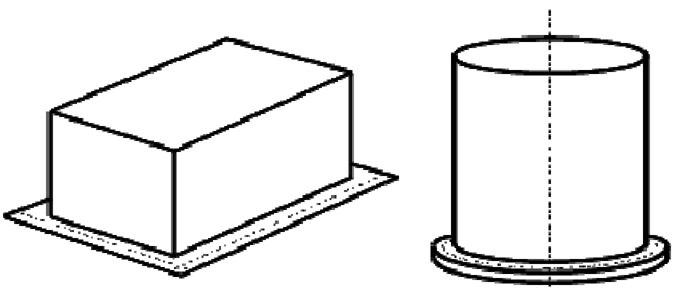
The advice is largely unchanged noting that calculation of design stresses is conventional - bending and shear within the trunnion and consequent stresses in the welded or bolted attachment must be considered. Refers to BS ISO 10276:2010 Trunnions for packages used to transport radioactive material for further information.

Corner ties
Lashings are connected between attachment points on the package and anchor points on the bed of the conveyance.



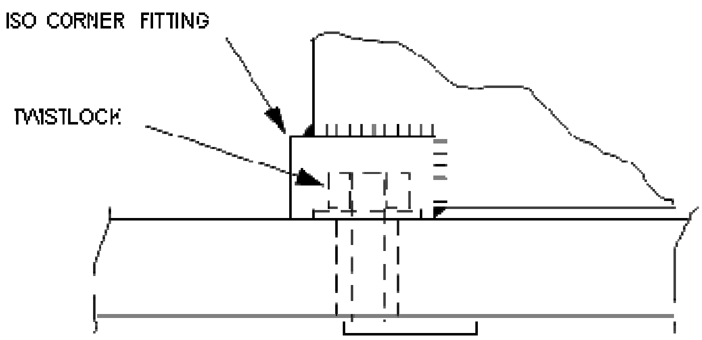
It is strongly recommended that the package is chocked in all directions and that the ties should be pre-tensioned to reduce shock loading and fatigue damage. The formula that was included calculated the lashing pre-load tension that had to be applied to the lashings. The pre-load tension is limited by the capacity of the ratchet device used and has to be measured which is not generally practical. The formula has been removed and reference is made instead to the formulae in the IAEA Advisory material TS-G-1.1 or BS EN 12195-1 which calculate the load induced in the lashings or to calculation from first principles.

Directly bolted
The package is bolted either to a transport frame or directly to the conveyance.



The formula for cylindrical packages has been removed because the assumptions made could introduce significant errors for packages secured by a small number of bolts. Reference is again made to TS-G-1.1 and to the use of finite element analysis which is far more straightforward these days.

ISO twistlocks
Used with ISO corner fittings as a tie-down system for ISO freight containers.



Standard twistlocks and corner fittings can be used without the need for additional design calculations. If non-standard corner fittings and twistlocks are used it is necessary to demonstrate that the system will withstand the load conditions specified in TCSC 1006.

Over Strapping
Lashings are positioned over the top of the package and secured to the vehicle. This method is also known as top-over lashing or frictional lashing.

If chocks are not used over strapping relies on the lashing tension pressing the package into the vehicle bed increasing the frictional resistance and preventing the package from sliding. Typically webbing lashings are used and the tension applied using ratchet tensioners. Reference is made to the formulae in BS EN 12195-1 for calculating the rating and quantity of lashings required. This method is likely to be limited to packages weighing less than a few tonnes.

This system was reviewed in detail by a TCSC sub-committee since it appears to contravene the guidance in TS-G-1.1 paragraph IV.15 which states that "Friction between the package and the conveyance platform is to be ignored and can only be regarded as a bonus giving an additional but unquantifiable margin of safety". Advice was also sought from the UK Competent Authority. It was agreed that since the additional frictional resistance induced by the lashings can be calculated so the margin of safety is quantifiable, the system is acceptable but that suitable caveats must be applied to ensure it is correctly used. In particular an upward acceleration factor must be applied which effectively negates the frictional resistance due to the mass of the package. This may be another case where the advice in TS-G-1.1 needs updating to reflect current transport practice.

Self retaining
The package is retained under its own weight in a stillage or a well. This typically applies to very large packages weighing tens of tonnes or drums carried in stillages. The designer must ensure that the magnitude and duration of the applied accelerations are not sufficient to lift the package out of the chocks or stillage.

Unsecured
This section originally referred to unrestrained packages however in most cases some form of restraint is applied and unsecured was considered a more appropriate term. This refers to situations where there is no tie-down system to positively secure the package to the conveyance but where restraint is achieved by restricting the movement of the package by the use of packing often referred to as dunnage or systems such as restraining bars.

Lightweight (less than 25kg), inherently stable packages may be transported totally unrestrained in an enclosure such as a van but any package carried in an estate car or similar vehicle where there is no bulkhead to protect the driver should be restrained.

4.5 PAYLOAD RESTRAINT

A new section has been introduced addressing payload restraint noting that it may be necessary to restrain the payload (the radioactive contents) within a package to prevent damage to the package during transport. The same provisions and methodology apply to payload restraint as apply to the securing of a package to a conveyance and similar systems can be used.

4.6 TRANSPORT FRAMES

A new section has been introduced addressing specific requirements applicable to transport frames (sometimes called tilt frames).

The first point considers whether a transport frame is effectively part of the package design and should therefore be attached to the package during design impact testing. The reasoning is that if the restraint should fail, the transport frame may remain attached to the package and the assembly subjected to any resultant impact. It is therefore desirable that during an accident the package should detach from the transport frame which remains attached to the conveyance.

The second point considers the transport of very heavy loads, particularly where the mass of the package exceeds that of the conveyance. When considering lateral and vertical accelerations, the loads imposed on the tie-down system may be limited by the mass of the conveyance rather than the mass of package. For example, the lateral forces may cause a rail wagon to overturn before the calculated tie-down load is reached. The additional restrictions applied to the transport of loads of this type are such that in practise overturning would not occur. If reduced acceleration factors are used taking note of the weight and geometry of the conveyance, the required strength and hence size and weight of the transport frame may be reduced. This can make a significant difference when heavy loads are considered.

It is noted that proposals of this nature should be discussed with the appropriate Competent Authority.

5. Conclusions

The TCSC Transport of Radioactive Material Code of Practice, TCSC 1006, now titled Guide to the Securing/Retention of Radioactive Material Payloads and Packages During Transport has been comprehensively reviewed and updated and was issued in December 2012 following approval by the members of the TCSC. The revised Code of Practice is available to members and associate members of the TCSC on the TCSC website www.tcsc.org.uk.

In reviewing the code it became apparent that there are a number of inconsistencies in the IAEA Regulations and Advisory Material regarding Routine and Normal Conditions of transport as applied to tie-down. The documents advise that tie-down systems do not have to withstand Normal Conditions of transport which is not consistent with the definition of Normal Conditions of Transport which includes minor impacts with vehicles and obstacles, rail shunting, heavy seas, turbulence or rough landings in air transport. TS-G-1.1 Table IV.1 is stated to apply to Routine Conditions of transport but the acceleration factors are higher than those in the IMO Guidelines which are internationally accepted for the transport of dangerous goods. It is suggested that references to routine and normal conditions of transport in the IAEA Regulations and Advisory Material should be reviewed along with the suggested acceleration factors.