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TCSC

Transport Container Standardisation Committee

Transport of Radioactive Material Code of Practice

Testing of Package Types IP-2, IP-3 and Type A

Publisher TCSC

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This Code of Practice has been prepared by the Transport Container Standardisation Committee (TCSC).

The purpose of the TCSC is "to examine the requirements for the safe transport of radioactive material with a view to standardisation and, as appropriate, produce and maintain guidance in the form of standards documentation". The TCSC began as an industry forum in the 1960's and has supported the radioactive materials transport industry for more than fifty years. In 2013 the TCSC was registered at Companies House as a company limited by guarantee.

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Foreword

Testing a package design is often a time consuming and expensive exercise. It is therefore important that not only is it carried out correctly, but that the testing, and all the associated activities, are performed efficiently so as to minimize cost. The IAEA advisory material, SSG-26, contains a lot of advice on technical aspects of testing. The purpose of this document is to take a broader view of the process and offer guidance on related aspects that can ultimately be as important as the testing itself. A perfectly executed series of tests are useless if subsequently the philosophy of the test method is challenged and rejected.

This document provides guidance on the testing of Type IP-2, Type IP-3 and Type A Packages. It represents good practice and takes the form of recommendations. It should be noted that the word “shall” denotes a requirement; the word “should” denotes a recommendation; and the word “may” denotes permission, neither a requirement nor a recommendation. Imperative statements also denote requirements.

1. Introduction

This Code of Practice provides guidance on the testing of package designs for the transport of radioactive material that are subject to Self Assessment and Approval. The package Types within the scope of this code are:

- Industrial Package Type 2 (Type IP-2),
- Industrial Package Type 3 (Type IP-3),
- Type A Package.

This covers a wide range of package sizes and styles ranging from simple fibreboard boxes, flexible bags, plastic or steel drums and containers, metal boxes of all sizes (including ISO freight containers) to fabricated lead/steel packaging. Such packages may comprise a single packaging with a simple closure or may include a separate containment or a complex closure.

Packages must comply with the test requirements of the IAEA Regulations for the Safe Transport of Radioactive Material (reference 1). While the Advisory Material for the Regulations (reference 2) contains further advice regarding package testing, this Code of Practice is intended to complement the Advisory Material by providing practical advice.

The IAEA Regulations adopt a graded approach to the contents limits for packages and the performance standards applied to package designs depending on the hazard of the radioactive contents. The performance standards are characterised in terms of three general severity levels:

- Routine conditions of transport (incident free),
- Normal conditions of transport (including minor mishaps),
- Accident conditions of transport.

Excepted and Type IP-1 packages are designed for routine conditions of transport and are not subject to regulatory testing.

Type IP-2, Type IP-3 and Type A packages are designed to withstand normal conditions of transport and are subject to the specified tests for demonstrating ability to withstand normal conditions of transport. Due to the lower hazard presented by the contents, Type IP-2 packages are not subjected to all of the normal conditions tests, whereas additional tests are specified for Type A packages designed for liquids and gases which have a greater possibility of leakage. Guidance on Self-Assessment and Approval of Package Types IP-1, IP-2, IP-3 and Type A is provided in TCSC 1078 (reference 3).

Type B and Type C packages are designed for accident conditions of transport and are subject to the tests for demonstrating ability to withstand accident conditions of transport. The testing of packages requiring Competent Authority Approval is excluded from this Code of Practice. Advice on the drop testing of Type B packages is provided in TCSC 1086 (reference 4).

This Code of Practice also provides guidance on the use of packages tested in accordance with the alternative requirements for Type IP-2 and IP-3 Packages as allowed by the IAEA Regulations. Specific guidance on the use of ISO freight containers as Type IP-2 Packages is provided in TCSC 1090 (reference 5).

It is recommended that the Test Plan is submitted to the Design Authority and the Approval Authority as appropriate for agreement prior to testing. It may be beneficial to discuss test proposals with these Authorities during preparation of the Test Plan.

Approval Authority

An organisation or an individual responsible for the approval of radioactive material package designs.

Design Authority

An organisation or an individual responsible for the specification and design of the packaging.

2. Regulatory Requirements

The test requirements for the various package types are specified in the following paragraphs of the IAEA Regulations (reference 1).

Note if a package is required to carry fissile material excepted by para 674(b) then the requirements specified below for that paragraph must be met

Type IP-2

Paragraph 624

A package to be qualified as a Type IP-2 shall be designed to meet the requirements for Type IP-1 as specified in para. 623 and, in addition, if it were subjected to the tests specified in paras 722 and 723, it would prevent:

(a) Loss or dispersal of the radioactive contents;

(b) More than a 20% increase in the maximum radiation level at any external surface of the package.

Type IP-3

Paragraph 625

A package to be qualified as a Type IP-3 shall be designed to meet the requirements for Type IP-1 as specified in para. 623 and, in addition, the requirements specified in paras 636–649.

The test requirements are specified in paragraph 648

A package shall be so designed that if it were subjected to the tests specified in paras 719–724, it would prevent:

(a) Loss or dispersal of the radioactive contents;

(b) More than a 20% increase in the maximum radiation level at any external surface of the package.

Note also that should a package be required to carry fissile material excepted by the provisions of para 674(b) a water spray test and penetration test as defined by in paras 721 and 724 must be performed.

Type A

The test requirements for a Type A package are specified in paragraph 635 as noted above for Type IP-3.

Type A – Liquid

Additional requirements for Type A packages designed to contain liquids are specified in Para 650.

Paragraph 650

A Type A package designed to contain liquid radioactive material shall, in addition:

(a) Be adequate to meet the conditions specified in para. 648(a) if the package is subjected to the tests specified in para. 725; and

(b) Either:

i Be provided with sufficient absorbent material to absorb twice the volume of the liquid contents. Such absorbent material must be suitably positioned so as to contact the liquid in the event of leakage; or

ii Be provided with a containment system composed of primary inner and secondary outer containment components designed to enclose the liquid contents completely and to ensure their retention within the secondary outer containment components, even if the primary inner components leak.

Type A - Gas

Additional requirements for Type A packages designed to contain gases are specified in Para 651.

Paragraph 651

A package designed for gases shall prevent loss or dispersal of the radioactive contents if the package were subjected to the tests specified in para. 725. A Type A package designed for tritium gas or for noble gases shall be excepted from this requirement.

Packages containing fissile material excepted by para 674(b)

Paragraph 674(b)(ii)

The package, after being subjected to the tests specified in paras 719–724:

- *retains its fissile material contents;*
- *preserves the minimum overall outside dimensions of the package to at least 30 cm;*
- *prevents the entry of a 10 cm cube.*

Tests

The specified tests are:

Para 721: Water Spray Test

Para 722: Free Drop Test

Para 723: Stacking Test

Para 724: Penetration Test

Para 725 (a): Enhanced Free Drop Test

Para 725 (b): Enhanced Penetration Test

The detailed test requirements are considered in section 6 and the pass/fail criteria in section 7 of this document.

Where the contents of a Type IP-3 Package comprise LSA-III material, testing of the material may be necessary to demonstrate that it is relatively insoluble. Such testing is beyond the scope of this document which is concerned with package testing.

3. Alternative Requirements for Type IP-2 and Type IP-3

The IAEA Regulations (reference 1) list "Alternative requirements for Type IP-2 and Type IP-3" which permit certain standard package designs to be used as Type IP-2 and Type IP-3 packages subject to certain conditions. The relevant paragraphs are as follows:

3.1. UN Approved Packages

Para 626: Packages may be used as Type IP-2 provided that:

(a) *They satisfy the requirements for Type IP-1 specified in para. 623.*

(b) *They are designed to satisfy the requirements prescribed for UN Packing Group I or II in Chapter 6.1 of the United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations (reference 6).*

(c) *When subjected to the tests required for UN Packing Group I or II, they would prevent:*

(d) *Loss or dispersal of the radioactive contents;*

(e) *More than a 20% increase in the maximum radiation level at any external surface of the package.*

The Advisory Material (reference 2) notes that the use of UN packagings is allowed because the UN Recommendations (reference 6) for Packing Groups I and II (marked X or Y respectively under the UN marking system) have comparable design standards and require the same or even more stringent performance test standards compared with those for Type IP-2 packages.

Although the UN drop test requirements may be more stringent in that they require the testing of multiple packages from a greater height in some cases, they do permit transient leakage from a package. The UN Recommendations (reference 6) state that "a slight discharge from the closure(s) upon impact is not considered to be a failure of the packaging provided that no further leakage occurs". The Advisory Material (reference 2) notes that this discharge would not meet the requirement of the IAEA Regulations (reference 1) for no loss or dispersal of the contents. UN packagings shall only be used as Type IP-2 packages if it can be shown that no such discharge occurred during the drop test.

There is no test criteria regarding shielding in the UN tests so this requires special attention if UN packagings are used.

The Advisory Material (reference 2) notes there should be consistency between the contents being shipped and the contents tested in the United Nations tests, including consideration of maximum relative density, gross mass, maximum total pressure, vapour pressure and the form of the contents. The contents used in testing must be of a similar nature to the actual contents so that the test results demonstrate that a package carrying radioactive contents would not fail when subjected to the drop test. For drums approved for solids, UN tests are often performed using sand and granular materials - such a drum should not be approved for the transport of larger solid items because the behaviour of such items when tested is significantly different to granular payloads. If necessary, a drop test should be undertaken with a representative payload.

The stacking test for UN packagings may be performed with the package completely full of material. Experience has shown that a partially filled plastic drum, will fail at a lower stacking test load. If a UN plastic drum is to be approved as an IP-2 package it is recommended that a stacking test should be performed with a representative payload unless the contents will always completely fill the drum.

Para 626(c) does not stipulate that a package be "designed" to meet the sub-paras (i) or (ii). This is in recognition that UN packages are commercial off the shelf products and it may not practicable for the designer to re-approve them for each class 7 usage. For UN packages the consignor shall produce or obtain documentary evidence of testing, calculation or reasoned argument that the requirements of para 626(c) would be met for the intended contents.

3.2. Portable Tanks

Para 627: *Portable tanks may also be used as Type IP-2 or Type IP-3, provided that:*

(a) They satisfy the requirements for Type IP-1 specified in para. 623;

(b) They are designed to satisfy the requirements prescribed in Chapter 6.7 of the United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations, or other requirements at least equivalent, and are capable of withstanding a test pressure of 265 kPa; and

(c) They are designed so that any additional shielding which is provided shall be capable of withstanding the static and dynamic stresses resulting from handling and routine conditions of transport and of preventing more than a 20% increase in the maximum radiation level at any external surface of the portable tanks.

The Advisory Material (reference 2) notes that portable tanks designed for the transport of dangerous goods according to international and national regulations have proved to be safe in handling and transport, in some cases even under severe accident conditions. The general design criteria for tank containers with respect to safe handling, stacking and transport can be complied with if the structural equipment (frame) is designed in accordance with ISO 1496-3 (reference 7). For radioactive material (without other dangerous properties), portable tanks designed according to ISO1496-3 (reference 7) are considered to be at least equivalent to those that are designed to the standards prescribed in Chapter 6.7 of the UN Recommendations (reference 6).

The shielding retention requirement (para. 627(c)) is complied with if after the tests the shielding material remains in place, shows no significant cracks and permits no more than a 20% increase in the radiation level as evaluated by calculation and/or measurements under the above mentioned conditions. In the case of tank containers with an ISO framework, the radiation level calculations/measurements may take the surfaces of the framework as the relevant surfaces.

Reference in para. 627(b) to other requirements at least equivalent refers to the modal transport regulations specifically:

ADR Agreement (reference 8) Chapter 6.7

RID Regulations (reference 9) Chapter 6.7

IMDG Code (reference 10) Chapter 6.7

3.3. Other Tanks

Para 628: *Tanks, other than portable tanks, may also be used as Type IP-2 or Type IP-3 for transporting LSA-I and LSA-II liquids and gases as prescribed in Table 5, provided that:*

(a) They satisfy the requirements for Type IP-1 specified in para. 623;

(b) They are designed to satisfy the requirements prescribed in regional or national regulations for the transport of dangerous goods and are capable of withstanding a test pressure of 265 kPa;

(c) They are designed so that any additional shielding which is provided shall be capable of withstanding the static and dynamic stresses resulting from handling and

routine conditions of transport and of preventing more than a 20% increase in the maximum radiation level at any external surface of the tanks.

The Advisory Material (reference 2) notes that equivalent standards for road tank vehicles, rail tank wagons and tank containers have been introduced in a separate Chapter 6.8 of ADR (reference 8) and RID (reference 9), which specifies an acceptable equivalent safety level. Chapter 6.8 of the IMDG Code (reference 10) includes provisions for the transport of road tank vehicles by sea.

3.4. ISO Freight Containers

Para 629: *Freight containers with the characteristics of a permanent enclosure may also be used as Type IP-2 or Type IP-3, provided that:*

(a) The radioactive contents are restricted to solid materials.

(b) They satisfy the requirements for Type IP-1 specified in para. 623.

(c) They are designed to conform to the International Organization for Standardization document ISO 1496/1: Series 1 Freight Containers — Specifications and Testing — Part 1: General Cargo Containers for General Purposes, excluding dimensions and ratings. They shall be designed such that if subjected to the tests prescribed in that document and to the accelerations occurring during routine conditions of transport they would prevent:

i Loss or dispersal of the radioactive contents; and

ii More than a 20% increase in the maximum radiation level at any external surface of the freight containers.

The Advisory Material (reference 2) notes that freight containers designed and tested to ISO 1496-1 (reference 11) and approved in accordance with the CSC Convention (reference 12) have been proved, by the use of millions of units, to provide safe handling and transport under routine conditions of transport. Freight containers designed and tested to ISO 1496-1 are restricted to the carriage of solids because they are not regarded as being suitable for free liquids or liquids in non-qualified packagings.

To comply with the IAEA Regulations, ISO freight containers will usually need to be purpose designed to qualify as IP-2 packages. It is unlikely that standard, commercial, ISO freight containers would satisfy the regulatory requirements unless it can be shown that the material form is such that the requirement to ‘prevent loss or dispersal of the radioactive contents’ can be satisfied.

The UK Competent Authority has produced a Guide to the Approval of Freight Containers as Type IP-2 and Type IP-3 Packages (reference 13) which requires that the prototype package must be shown to be leak tight before, under loaded conditions and after the ISO load tests. TCSC 1090 (reference 5) which incorporates this guidance and gives guidance on the requirements for the design, manufacture, testing, approval, operation and maintenance of ISO freight containers for use as Type IP-2 packages, should be referred to. Given that freight containers, when used as packaging rather than overpacks, are usually transported under exclusive use the need for Type IP-3 is rarely required.

3.5. Metal IBC’s

Para 630: *Metal IBCs may also be used as Type IP-2 or Type IP-3, provided that:*

(a) They satisfy the requirements for Type IP-1 specified in para. 623;

(b) They are designed to satisfy the requirements prescribed for UN Packing Group I or II in Chapter 6.5 of the United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations, and if they were subjected to the tests

prescribed in that document, but with the drop test conducted in the most damaging orientation, they would prevent:

- *i Loss or dispersal of the radioactive contents; and*
- *ii More than a 20% increase in the maximum radiation level at any external surface of the IBC.*

The Advisory Material (reference 2) notes that the use of UN packagings is allowed because the UN Recommendations (reference 6) for Packing Groups I and II (marked X or Y respectively under the UN marking system) have comparable design and performance test requirements to those for Type IP-2 and Type IP-3 packages. The Advisory Material (reference 2) imposes an additional requirement for IBC's with more than 0.45 m^3 capacity that the drop test is performed in the most damaging position (and not only onto the base).

There is no test criteria regarding shielding in the UN tests so this requires special attention if UN approved IBC's are used.

The Advisory Material (reference 2) notes that the alternative use of IBC's is restricted to metal designs only because they provide the closest match with Type IP-2 and Type IP-3 package requirements stating that the need for other design types could not be identified, and they do not seem to be appropriate for the transport of radioactive material. Other design types such as plastic IBC's may be suitable for the transport of radioactive materials, however if other design types are used, they cannot be approved under the alternative requirements of the regulations which are specific in allowing only metal IBC's. The tests required for UN approval may permit other IBC designs to be approved as IP-2 or IP-3 packages under the basic requirements of the IAEA regulations (paras. 624 and 625) considered in section 2 of this Code of Practice.

Para 6.5.6.1.2 of the UN Recommendations (reference 6) requires that:

Tests shall be carried out on IBCs prepared for transport. IBCs shall be filled as indicated in the relevant sections. The substances to be transported in the IBCs may be replaced by other substances except where this would invalidate the results of the tests. For solids, when another substance is used it shall have the same physical characteristics (mass, grain size, etc.) as the substance to be carried. It is permissible to use additives such as bags of lead shot, to achieve the requisite total package mass, so long as they are placed so that the test results are not affected.

There must therefore be consistency between the contents to be carried and the contents tested in the UN tests. If the nature of the radioactive contents is not consistent with the test contents, further tests must be performed with representative simulated contents.

4. Specification of Package to be Tested

The reason a package is tested is to demonstrate that the package design satisfies the IAEA regulatory test requirements so the ideal test specimen is one that can demonstrate the performance of a transport package with least uncertainty. It is advisable to discuss the specification of the test specimen with the Design Authority and Approval Authority prior to testing.

4.1. Prototype v Production

Ideally the test specimen will be identical to the production package in all respects, including geometry, material, manufacturing process, QA requirements and assembly process. In this case, the behaviour of the test specimen represents the behaviour of the actual package under the same conditions. There will be little uncertainty in relating the test results to the performance of the actual package except for any variation of performance arising from manufacturing tolerances and permissible variation of material properties.

For simple packages made up from proprietary items such as fibreboard boxes, or steel or plastic drums and containers this is straightforward. The items tested match the production package (apart from manufacturing variations) and the behaviour under test will give an accurate representation of the production package.

The next best option for a test specimen is a prototype – i.e. a pre-production version of the package. Ideally the prototype test specimen will be identical to the production package. If the design, manufacturing or assembly processes are modified between the prototype and the production version, all the differences will need to be catalogued and evaluated to demonstrate that any difference is:

- cosmetic and has no effect on the package performance,
- potentially significant, but that the prototype is inferior, or
- significant but will not affect the test results (e.g. the difference is confined to an area that would not be damaged in a test.)

4.2. Materials

Since the strength and behaviour of the test specimen should be the same as the package design, the materials used in the construction of a test specimen should match the package design. They should be of the same thickness and the same grade.

While the use of lower grade materials may appear acceptable for the prototype, (since the production version will therefore always be stronger), such an approach needs careful consideration. For example if the test specimen is not as strong it may experience more damage in the drop test. But that increased damage (knockback) will mean that the package, any internal components and the payload experience a lower deceleration and hence a lower force. The greater forces experienced when applied to the production package could damage the internal components or result in an increased demand on key components of the package structure, containment boundary or shielding effectiveness.

Any variation in the materials used in the construction of the test specimen must therefore be fully justified.

Even if the material of the test specimen is of the same grade as the production package there will be variations in the mechanical properties within the standard for that grade of material resulting in small differences in the performance of the test specimen when compared to the production model. If post-test inspection indicates that key components of the test specimen show signs of unexpected damage an assessment of the effect that material properties would have on the performance of the package should be made. This would apply where there is no release of contents but inspection shows that a small variation in the performance of the materials could result in such a release. Typical examples of damage might be;

- Partial release of a drum closure ring (even if the drum lid remains attached with no release of contents).
- Near failure of a seal or gasket indicated by the presence of test dust across most or all of its width.
- A cracked weld.
- The presence of cracks in the body of a specimen.

In such circumstances, it is recommended that the design is subject to review, changes made and design verified by calculation, followed by demonstration through testing.

Where shock absorbing materials form part of the package design those used in the test specimen must again match the production package.

Fasteners should be of the same size, material and grade and all components should be to the same specification as the production package.

Care should be taken to replicate the properties of seals and sealing systems using the same materials as the production package. The geometric configuration of ‘O’ ring grooves must be replicated.

The performance of materials may also degrade with changes in temperature (e.g. embrittlement of steel or elastomers at low temperatures, or melting of plastics at high temperature).

The temperatures a package is subjected to may be defined as;

> Operating temperature range: The temperature range within which the package is inherently safe to operate. (For example -10°C to 70°C where steel components may embrittle below -10°C or where plastic loses its strength above 70°C)..
>
> Allowable temperature range: A, potentially larger, temperature range within which the materials used would not undergo any permanent change in mechanical or thermal properties once they return to the operating temperature range

Provided that the materials recover their properties after being exposed to temperatures outside the operating range, but within the allowable range there is generally no need to perform testing at anything other than ambient temperature.

However, consideration must be given to loss of performance and it may be necessary to impose an operational control to prohibiting shipment at temperatures that are outside the operating range that the package is designed for.

4.3. Structure

The construction of the test specimen must coincide with the production model as far as possible. Welds must be of the specified size. They must not be larger than specified as may normally be acceptable since that would strengthen the test specimen.

The method of manufacture should match that of the production package. e.g. if rolled steel sections or pressed plates are specified (where a degree of work hardening would influence the material properties) they must be used, fabricated welded sections would not be acceptable. If used, the production design would have to be altered to match, otherwise any variation in the method of manufacture of the test specimen must be justified.

Any changes to the design or construction methods during manufacture of the test specimen (concessions or production permits) should either be incorporated into the design of the production package or must be justified as not affecting the performance during testing.

4.4. Containment

Where the package design incorporates a separate containment which may be a machined or fabricated structure the considerations raised in 4.2 and 4.3 apply.

4.5. Shielding

Where a package design includes shielding, this must be replicated in the test specimen so that the effects of the tests on the shielding can be assessed since one of the purposes of testing is to determine if there has been any loss of shielding integrity. The shielding materials and construction should match that of the production package.

Similarly if the dose is reduced due to the radioactivity being centred with the packaging to rely on distance the position of the radioactive material in the packing post impact testing must be assessed. Any internal furniture should also be replicated in the test specimen.

The criteria for loss of shielding integrity is given in paras 624 for IP-2, 648 forIP-3 and Type A, these state that there shall be no more than a 20% increase in the maximum dose level at any external surface of the package.

If the radioactive material is evenly distributed throughout the payload (e.g. a contaminated granular material) then the surface dose level will be uniform over most of the surface with the highest at the base. This is dependent on the geometry of the package. For a typical 205 litre drum, the maximum surface dose level would be at the base. (Assuming that the drum is not brim-full.)

However, if the material is an irradiated component or a small source the maximum dose will be at the thinnest part of the shield or the smallest outer surface to source distance.

Ductile/malleable shielding materials such as lead may slump during impact testing and brittle materials such as tungsten or concrete may fracture or have their effectiveness reduced. The materials should be replicated so that these effects can be properly assessed.

The furniture used to position the source or component should preferably be semi rigid, and its condition assessed post-test to demonstrate that the source has not moved to such an extent that the dose rate would increase by more than 20% at the package surface.

Materials such as vermiculite or loose fill polystyrene may settle in routine conditions (due to vibration) and normal condition of transport (due to impact).

It should also be noted that it is unacceptable to place the source against the inner surface of the package such that it would only move away from the surface in and impact or under vibration. This would contravene para 301 which essentially states that dose levels should be as low as reasonably achievable.

Assessment of the effects of source movement, damage to shielding materials or reductions in distance (e.g. due to knockback at impact) on the surface dose level is required. This change in geometry is acceptable provided the increased level is less than 20% greater than the original maximum radiation level (which may be at another position on the package surface). This may be assessed by calculation, reasoned argument or measurement.

4.6. Gross Mass

The gross mass of the test specimen will set the operating weight limit for the package design. It is therefore important that the gross mass of the test specimen matches or exceeds the maximum that the package is designed to carry. It may be considered prudent to increase the test specimen gross mass to provide a margin for mass of permissible contents for the package design.

4.7. Quality Assurance

Complete Quality Assurance records must be obtained for the test specimen including any proprietary items used. The Quality Assurance records may include:

- Material certificates.
- Weld procedures and welder qualifications.
- NDT Reports and Operator Qualifications.
- Inspection reports (e.g. dimensional inspection).

- Certificates of Conformity for proprietary items.
- Calibration certificates for equipment used.
- Leakage test results.
- Quantity, location and type of tracer materials.
- Simulated contents definition.
- Design drawings and other specifications

In the case where a proprietary item is sourced (e.g. UN approved drum) a Declaration of Conformity for that item should be sought form the manufacturer/supplier)

4.8. Finish

Since the finish (paint or coating) does not usually influence the behaviour under test it is not necessary for the test specimen to be finished. Apart from the cost benefit, this can have advantages in enabling better visual inspection.

It is not usually necessary to attach permanent labels (other than those indicating specimen details) to the test specimen.

4.9. Scale Model

Although the use of a scale model (no smaller than ¼ scale) is permissible and has been shown to be effective there are problems associated with the production and justification of a scale model. For instance:

- A 6 mm fillet weld is difficult to replicate at ¼ scale.
- Specified material properties vary with stock thickness, and indeed may not be scalable – toughness tends to decrease with increasing thickness.
- Standard steel sections may not be available in smaller sizes and need to be fabricated.
- Fastener thread sizes do not scale directly since strength is proportional to core area.

Scale model testing is not normally used for Type IP-2, IP-3 or Type A packages. It is mainly applicable to more complex and expensive Competent Authority approved package designs. The use of scale models is a specialist area and if required expert advice should be sought.

4.10. Single Package v Combination

Simple Type IP-2 and IP-3 packages may comprise a single packaging (e.g. a steel or plastic drum) or may comprise a combination package where one or more inner packagings are contained within an outer packaging. Type IP-2/IP-3 packages do not typically include shielding. Type A packages will generally incorporate shielding and in many cases will be combination packages with a separate inner containment or primary and secondary containments for liquids. The shielding may be incorporated into the containment, it may form a separate component of the packaging or may be incorporated into the outer packaging.

The test specimen must replicate all aspects of the design to be tested so that any loss of contents or reduction in shielding can be properly assessed.

5. Contents of test Specimen

5.1. Stimulated Contents

Due to the hazard and risk that would result from testing a package with the radioactive contents for which it is designed, it is usual for tests to be performed with simulated contents that are representative of the radioactive contents. SSR-6 Para. 701 requires that the contents shall simulate as closely as practicable the expected range of radioactive contents.

It is essential to determine the mechanical properties, geometry and conditions of the contents and replicate these as far as possible for testing purposes. It is advisable to discuss the proposed contents with the Design Authority and Approval Authority prior to testing.

5.2. Chemical Form

If the chemical form of the contents present other hazards (pyrophoric, corrosive, toxic, flammable, oxidising etc.) it may not be possible to use such contents due to the possible resultant hazard following a test failure. Since the chemical form of the contents would not be expected to affect the test results, simulated contents may be used (e.g. water may be used instead of nitric acid).

5.3. Physical Form

The physical form of the contents must be representative of the intended radioactive contents, including the condition.

5.3.1. Solid

A package intended for the transport of solid material must be tested with solid material of similar density. Since the impact of the payload on the lid of the package or containment can have a significant effect on the behaviour of the package, the nature of the simulated contents must correspond with the actual contents. If the package is to carry large items of contaminated steel it must be tested with similar large items of steel. If the contents have hard protrusions or pointed ends which may damage the inside of the package these must be represented in the simulated contents. If granular materials (e.g. soil, gravel, crushed concrete) are to be carried the simulated payload must be representative particularly if the contents include fine powders.

5.3.2. Liquid

A package intended for the transport of liquid material must be tested with liquid material. It should be of similar relative density and viscosity to the radioactive material to be carried in the package since either of these factors can affect the performance of a package. However a simulant liquid of lower viscosity is more likely to leak from a package so would be acceptable. Similarly a simulant of higher relative density is acceptable since this will increase the package mass resulting in greater damage. e.g. testing with water would be acceptable for a package intended to carry oil.

5.3.3. Gas

A package intended for the transport of gas must be tested with gaseous material. Since such a package will usually be pressurised the test specimen must be similarly pressurised, and the pressure assessed before and after testing to determine the effectiveness of the containment system. This may be difficult if the volume of gas carried is small. It may be possible to weigh the pressure vessel before and after testing.

5.3.4. Sludge

Packages carrying sludges (a mixture or suspension of fine solid particles in a liquid) are more difficult given the variable nature of the contents. A sludge is typically simulated by a mixture of sand and water. The condition for the tests should replicate the condition of the sludge when transported. This may require the test specimen to be shaken prior to testing but if it is likely that the sludge in the production package will settle out leaving free liquid at the surface in which case the simulant material should be allowed to settle to replicate this condition.

Since the IAEA Regulations (reference 1) only recognise solid, liquid or gaseous payloads it is necessary to determine whether the sludge constitutes solid or liquid radioactive material. This is mainly relevant to Type A Packages which require significantly enhanced tests for packages containing liquid radioactive material.

It is common to define sludges as liquids. However, since the enhanced test requirements only apply to Type A Packages containing liquid radioactive material, if it can be demonstrated that only the solid particles within a sludge are radioactive and the liquid is not (there is no dissolved activity in the liquid), the enhanced Type A tests for liquids are not required. The package should be tested with a representative payload including the liquid but would only be subject to the tests for a Type A Package containing solid radioactive material and not the enhanced tests for a Type A Package containing liquid radioactive material.

If the liquid within a sludge is radioactive, the enhanced Type A tests apply and there shall be no loss or dispersal of the radioactive contents (solid or liquid).

5.3.5. Change of State

If it is possible for the payload to experience a change of state during transport (e.g. liquid contents may freeze) such changes must be considered either in the test plan or in the justification. It is considered that a liquid payload presents a greater challenge than a solid payload so freezing of a liquid payload is not generally an issue. Allowance within the design should be made for corresponding changes in density e.g. freezing water will expand which could damage the package. It is therefore usual in testing to leave ullage space so that the liquid container is not completely full and the design intent is fully met.

5.3.6. Special Conditions

When the contents of a package are carried under specific conditions (e.g. uranium swarf immersed in oil or a package filled with an inert gas) the simulated contents must represent these conditions which must be maintained during testing.

5.4. Mass

The gross mass of the test specimen will set the limit for the package design so the mass of the test specimen must match or exceed the maximum that the package is designed to carry. This is best achieved by using a simulant material of similar density but if this is not possible the required gross mass may be achieved by other means as described below.

Light payloads such as wood/paper may be augmented with lead weights to achieve the required gross mass of a payload of mixed wastes. The weights should be placed in the middle of the payload so that the items do not have an undue influence on the test results due to internal impact on the packaging.

Dense powders may be simulated by the addition of lead shot to the simulant powder to replicate the mass and fluidity of the actual contents.

The mass and geometric configuration should be replicated so that the Centre of Gravity of the test specimen corresponds with the package design and production unit

5.5. Volume

The volume of the contents should match that of the package so that any free space in the package is replicated in the test specimen. Free space in a package allows the content to move and when subjected to a drop test this movement can have a “battering ram” effect causing greater damage to the package.

5.6. Tracer Materials

Tracer materials, usually fluorescent dust or dye can be added to the simulated contents so that any leakage can be more easily observed. If fluorescent dust is used a thin layer is usually spread over the surface of the contents and care should be taken to keep it dry. The outer surface of the test specimen and the test plate should be carefully cleaned to ensure they are free from fluorescent dust to improve accuracy of results.

When testing grouted contents e.g. radioactive powders mixed with cement it is possible also to mix fluorescent dye with the cement to detect if cement powder is ejected during an impact. It should be noted that when tracer material is ejected on impact it will be spread in a fan from the breach of the containment. A single point of fluorescent material is more likely to be contamination.

Trials should be undertaken to determine the mix ratio of dye to cement to ensure there is sufficient dye and that it is chemically compatible with the cement grout.

6. Tests Required

6.1. Normal Conditions of Transport Tests

SSR - 6 (reference 1) Para. 719

The tests are: the water spray test, the free drop test, the stacking test and the penetration test. Specimens of the package shall be subjected to the free drop test, the stacking test and the penetration test, preceded in each case by the water spray test. One specimen may be used for all the tests, provided that the requirements of para. 720 are fulfilled.

These tests are considered representative of minor mishaps that may occur under Normal Conditions of Transport. The Advisory Material (reference 2, para. 719.6) notes that it is sufficient for one each of three specimens to be subjected separately to the free drop, stacking and penetration tests, preceded in each case by the water spray test (if appropriate) although one specimen can be used for all tests. There is no specific requirement as to whether the tests are performed consecutively on one package or on separate packages. Either option is acceptable and it is up to the designer to decide how many specimens should be made. If the package is based on off the shelf, proprietary components, it is often easier to build two or three test specimens.

The following table summarises the tests required for each package type.

Test	SSR-6 paragraph	IP-2 [1]	IP-3	Type A	Packages containing fissile material excepted by para 674(b)
Water spray	721		✓	✓	✓
Free drop, up to 1.2m[2]	722	✓	✓	✓	✓
Stacking	723	✓	✓	✓	✓
Penetration, 1m	724		✓	✓	✓
Free drop, 9m	725(a)			✓[3]	
Penetration, 1.7m	725(b)			✓[3]	

1. IP-2 packages approved to the alternative requirements in para 626-630 are subject to different test standards by the UN model regulations, regional or national regulations or in the ISO 1496/1 Series 1 Freight Containers - Specifications and Testing standard.
2. For rectangular fibreboard or wood packages not exceeding a mass of 50 kg, a separate specimen shall be subjected to a free drop onto each corner from a height of 0.3m. For cylindrical fibreboard packages not exceeding a mass of 100 kg, a separate specimen shall be subjected to a free drop onto each of the quarters of each rim from a height of 0.3m.
3. Required for Type A Packages designed for liquids and gases

6.2. Water Spray Test

SSR-6 Para. 721

The specimen shall be subjected to a water spray test that simulates exposure to rainfall of approximately 5 cm per hour for at least one hour.

SSG - 26 Para 721.1

The water spray test is primarily intended for packagings that rely on materials that absorb water or are softened by water or materials bonded by water soluble glue. Packagings whose outer layers consist entirely of metal, wood, ceramic or plastic, or any combination of these materials, may be shown to pass the test by reasoned argument providing that they do not retain the water and significantly increase their mass.

Metal and plastic packages are not normally subjected to a water spray test which is particularly intended for packages that have potential to be degraded by water. The retention of water in small recesses such as the top of a drum should not be considered significant.

SS6 - 26 Paras 721.2 and 721.3 provides details of one method of performing the water spray test which is considered to satisfy the conditions prescribed in SSR -6 para 721. Reference should be made to these paragraphs if necessary.

The water spray test may be a fairly simple test using a simple hose fitted with a valve and flow meter and a suitable spray head. The flow meter can be calibrated to the required rate using a simple rain gauge and then used to set the flow rate corresponding to the rainfall requirement.

SSR - 6 Para. 720

The time interval between the conclusion of the water spray test and the succeeding test shall be such that the water has soaked in to the maximum extent, without appreciable drying of the exterior of the specimen. In the absence of any evidence to the contrary, this interval shall be taken to be two hours if the water spray is applied from four directions simultaneously. No time interval shall elapse, however, if the water spray is applied from each of the four directions consecutively.

6.3. Free Drop Test

SSR – 6 Para. 722

The specimen shall drop onto the target so as to suffer maximum damage in respect of the safety features to be tested:

(a) The height of drop measured from the lowest point of the specimen to the upper surface of the target shall be not less than the distance specified in Table 14 for the applicable mass. The target shall be as defined in para. 717.

(b) For rectangular fibreboard or wood packages not exceeding a mass of 50 kg, a separate specimen shall be subjected to a free drop onto each corner from a height of 0.3m.

(c) For cylindrical fibreboard packages not exceeding a mass of 100 kg, a separate specimen shall be subjected to a free drop onto each of the quarters of each rim from a height of 0.3m.

Table 1 – SSR-6 TABLE 14. Free Drop Distance for Testing Packages to Normal Conditions of Transport

Package mass (kg)	Free drop distance (m)
Package mass < 5000	1.2
5000 ≤ Package mass < 10000	0.9
10000 ≤ Package mass < 15000	0.6
15000 ≤ Package mass	0.3

Para. 722.1 of SSG-26 (reference 2) explains that the free drop test simulates the type of shock that a package would experience if it were to fall off the platform of a vehicle or if it were dropped during handling. It states that in most cases packages would continue the journey after such shocks. Since heavier packages are less likely to be exposed to large drop heights during normal handling, the free drop distance for this test is graded according to package mass. If a heavy package experiences a significant drop it should be examined closely for damage or loss of contents or shielding. Light packages made from materials

such as fibreboard or wood require additional drops to simulate repeated impacts due to handling.

Para. 722.2 states that any drop test should be conducted with the contents of the package simulated to its maximum weight and that more than one drop may be necessary to evaluate all possible drop attitudes. It may also be necessary to test specific features of the package such as hinges or locks to ensure that containment, and shielding are maintained.

Para. 722.3 notes that the features to be tested include structural components, materials and devices designed to prevent loss or dispersal of radioactive substances or loss of shielding material (e.g. the entire containment system, such as lids, valves and their seals).

Para. 722.4.

The 'maximum damage' is the maximum impairment of the integrity of the package. To produce the 'maximum damage' for most packages, the specimen should be dropped in one or more attitudes in such a way that the impact acceleration and/or deformation of the components under consideration is maximized. Most containers have some asymmetry giving different resistance to impact. In any investigation, sufficient structural elements should be considered to allow for the absorption of all the kinetic energy of the package. Arguments should be developed as to the damage in the various elements between the impact point and the concentration of mass with regard to their performance in absorbing the energy, in developing internal loads, in distorting, collapsing or folding, and in the consequences of these behaviours.

Para. 722.6 also refers to the drop test attitudes and notes that all possible drop test orientations need not be considered when conducting the drop test. Providing that it is not possible under 'normal' conditions for the package to be dropped in certain orientations, these orientations could be ignored in assessing the worst damage. This relaxation would only be allowed for large dimension and large aspect ratio packages and would require documented justification by the package designer.

For instance, a cylindrical package, 600mm in diameter and 800mm high, could topple off the back of a lorry and land in any orientation. In this case, the drop test would need to address all possible impact orientations. On the other hand, if a large box-like package, say 6m long and 2.5m wide, were to be dropped during normal handling it is likely to impact around the base, so it could be argued that a drop on to a top corner is not possible under 'normal' conditions and can be discounted. Furthermore large size usually means large mass and it may be argued that where large masses are concerned lifts are planned and well controlled so that any drop during lifting would be considered an accident rather than a minor mishap as may occur under Normal Conditions of Transport.

Careful consideration must be given to the package orientation chosen for the drop test(s). It is not just a case of dropping on the weakest part of the package to produce the maximum damage (e.g. the corner of a rectangular package). It may well be that a drop test which does little damage to the external packaging (e.g. on the flat surface of a package) but results in higher deceleration will result in more damage to the internal components or a greater challenge to the key components of the package structure, containment system or shielding.

Drop tests are normally performed with the Centre of Gravity (CoG) of the package directly above the point of impact to maximise the amount of the drop energy that needs to be absorbed by deformation of the package, and minimizes the amount of the drop energy that will be "lost" due to rigid body rotation of the package. The following orientations are normally considered for cylindrical and rectangular packages:

Cylindrical: flat on base, flat on lid, flat on side, CoG over lid edge and CoG over base edge.

Rectangular: flat on base, flat on lid, flat on long side, flat on short side, CoG over lid corner, CoG over base corner, CoG over lid short edge, CoG over lid long edge, CoG over base short edge and CoG over base long edge drop.

External features of the package such as catches or bolted closures, lifting features, valves or filters must be considered particularly when the external packaging provides direct containment of the radioactive contents. If the package includes a separate containment system within the outer packaging any features of the containment system that may impact the outer packaging must be considered.

For smaller, relatively inexpensive packages it is often possible to test several packages in various orientations. Alternatively a single package may be subjected to a number of drop tests in varying orientations. In many cases only one test will be performed e.g. a drum is usually dropped onto the lid closure with the Centre of Gravity directly above the point of impact. In the case of larger, more expensive packages finite element modelling may be preferred to determine the most damaging attitude so that only one test is required.

Whatever approach is adopted the selection of drop test orientation(s) must be technically justified and it is recommended that the test proposals are discussed with the Design/Approval Authority before testing commences.

Para. 722.5 states that packages of low mass might be hand held above the target and dropped, providing that the desired attitude can be maintained. This method is not commonly adopted because of the difficulty in maintaining the orientation of the package. Alternatively the package could be suspended on cord and this burned through to release the package if releasing by hand is not able to maintain the orientation.

Para. 722.5 continues that in all other cases, mechanical means should be devised to hold and release the package in the desired impact attitude. This could be simply a release mechanism suspended from an overhead structure, such as a roof member or a crane, or a tower specially designed for drop tests. The release mechanism for a free drop test should allow easy setting and instantaneous release, but should not give undesirable effects on the attitude of the specimen, and should not add to the mechanical damage to the specimen. Various types of mechanisms, such as mechanical or electromagnetic, or combinations of mechanisms could be used.

A simple method for lighter packages (< 30kg) is to suspend the package using nylon string which is released by burning through the string.

Specially designed brackets may be required to ensure the correct orientation of the package prior to release. Such brackets must be positioned to ensure that the test result is not compromised by the presence of such features. A procedure may be required to rotate the load safety. Calculations will be required to verify that the lifting equipment, including any special brackets, are adequate at all stages during the rotating process.

If the package weight is significant, and it is being dropped from a crane, the effect on the jib as the load is released should be considered. It is possible that a restraint may need to be fitted to prevent the jib recoiling and being overstressed.

For Type A Packages designed for liquids and gases, only the enhanced free drop test from 9m is required.

DROP TEST TARGET

SSR - 6 Para. 717 Target for drop tests

The target for the drop test specified in paras 705, 722, 725(a), 727 and 735 shall be a flat, horizontal surface of such a character that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase damage to the specimen.

Para. 717.1 of the SSG -26 (reference 2) notes that the target for drop tests is specified as an essentially unyielding surface which would cause greater damage to the package than that which would occur following an impact on an actual surface or structure during transport. The use of an unyielding target means that the test is repeatable which would not be the case if yielding targets were used.

Para. 717.2 gives an example of an unyielding target which would meet the regulatory requirements. This comprises a 40mm thick steel plate floated on to a concrete block mounted on firm soil or bedrock. The combined mass of the steel plate and concrete block should be at least 10 times that of the specimen for Type IP-2, IP-3 and Type A package drop tests. The steel plate should be keyed to the concrete which should be roughly cubic in form.

6.4. Stacking Test

SSR- 6 Para. 723

Unless the shape of the packaging effectively prevents stacking, the specimen shall be subjected, for a period of 24 h, to a compressive load equal to the greater of the following:

- *(a) A total weight equal to 5 times the maximum weight of the package;*
- *(b) The equivalent of 13 kPa multiplied by the vertically projected area of the package.*

The load shall be applied uniformly to two opposite sides of the specimen, one of which shall be the base on which the package would typically rest.

Para. 723.1 of SSG-26 (reference 2) notes that the stacking test is designed to simulate the effect of loads pressing on a package over a prolonged period of time to ensure that the effectiveness of the shielding and containment systems will not be impaired.

Packages with convex surfaces do not have to undergo a stacking test unless the package design incorporates features that allow it to be stacked.

The load applied to the package may not be due to a stack of identical packages, it could be due to any items placed on top of the package. It is not therefore sufficient justification to preclude the stacking test to state that the package is unique or that packages of this design will not be stacked.

TS-G-1.1 Para. 723.3

The specimen should be placed with the base down on an essentially flat surface such as a flat concrete floor or steel plate. If necessary, a flat plate, which has sufficient area to cover the upper surface of the specimen, should be placed on the upper surface of the specimen so that the load may be applied uniformly to it. The mass of the plate should be included in the total stacking mass being applied. If a number of packages of the same kind are stackable, a simple method is to build a stack of five packages on top of the test specimen. Alternatively, a steel plate or plates or other convenient materials with a mass five times that of the package may be placed on the package.

Guaranteeing the stability of the load can be a problem for certain packages. For instance, this could be because the package is high in comparison with its width, or because there is a possibility that a thin-shell component (e.g. an impact limiter or the wall of a plastic container) could partially collapse. If there is any risk of failure it will be necessary to provide temporary staging or to leave the load attached to a crane hook with the tension removed (but with the wire not excessively slack). If such measures are used care must be taken not to invalidate the test by removing some or all of the load from the package.

If a stack of packages is not used it is common practice to use lead or steel to make up the test load. For heavier packages a mechanical or hydraulic loading system may be required to apply sufficient load to the package.

Compliance with the stacking test may be demonstrated by calculation where it can be shown that the application of the specified load will have no significant effect on the package.

6.5. Penetration Test

SSG-26 Para. 724

The specimen shall be placed on a rigid, flat, horizontal surface which will not move significantly while the test is being carried out:

(a) A bar 3.2 cm in diameter with a hemispherical end and a mass of 6 kg shall be dropped and directed to fall, with its longitudinal axis vertical, onto the centre of the weakest part of the specimen, so that, if it penetrates sufficiently far, it will hit the containment system. The bar shall not be significantly deformed by the test performance.

(b) The height of drop of the bar measured from its lower end to the intended point of impact on the upper surface of the specimen shall be 1m.

SSG-26 Para *724.1*

The penetration test is intended to ensure that the contents will not escape from the containment system or that the shielding or confinement system would not be damaged if a slender object such as a length of metal tubing or a handlebar of a falling bicycle should strike and penetrate the outer layers of the packaging.

The test bar is usually delivered using a simple guide tube with a graduation mark to indicate the drop height.

As for the drop test, the impact location must be carefully considered. It is not just a case of dropping the bar on to the weakest part of the specimen. External features of the package such as catches or bolted closures, lifting features, valves or filters which may fail under the direct impact of the bar must be considered. It may be that an oblique impact with the specimen mounted at an angle is the most damaging.

A number of tests may be required although these can usually be performed on one specimen. The impact location(s) selected must be technically justified and it is recommended that the test proposals are discussed with the Design/Approval Authority before testing commences.

For Type A Packages designed for liquids and gases, only the enhanced penetration test from 1.7m is required.

6.6. Additional Tests for Type A Packages Designed for Liquids and Gases

SSG-26 Para 725

A specimen, or separate specimens, shall be subjected to each of the following tests unless it can be demonstrated that one test is more severe for the specimen in question than the other, in which case one specimen shall be subjected to the more severe test:

(a) Free drop test: The specimen shall drop onto the target so as to suffer the maximum damage in respect of containment. The height of the drop measured from the lowest part of the specimen to the upper surface of the target shall be 9m. The target shall be as defined in para. 717.

(b) Penetration test: The specimen shall be subjected to the test specified in para. 724, except that the height of the drop shall be increased to 1.7m from the 1m specified in para. 724(b).

SSG-26 Para . 725.1

These additional tests for a Type A package designed to contain liquids or gases are imposed because liquid or gaseous radioactive material has a greater possibility of leakage than solid material. These tests do not require the water spray test first.

6.7. Leakage Testing

For Type IP-2, IP-3 or Type A packages containing solids or liquids it is not common practice for a package to be pressurised during testing. It may however be necessary to demonstrate that that a package will retain pressure to comply with paragraph 616 in the general requirements of the IAEA Regulations (reference 1) which requires that “the design of the package shall take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport”. The ability to retain pressure may be demonstrated by leak testing the containment system, which may be the complete package, before and after testing or by reference to other pressure tests. The test pressure should be determined based on probable ambient temperature and pressures. Higher test pressures may be required to demonstrate compliance with paragraph 620 and paragraph 645 for Type A Packages.

The regulations do not require that a package is sealed, rather that there is no loss or dispersal of the radioactive contents. For packages carrying large or sealed radioactive items there may be no need to perform a leak test since the radioactive material could not escape even if there is a release of air. However if there is any possibility of airborne contamination within a package it must be demonstrated that this contamination cannot escape.

Advice on the leakage testing of packages can be found in TCSC 1068 (reference 14) or, ISO 12807:1996(EN) Safe transport of radioactive materials — Leakage testing on packages reference 16. Note that the latter document has been written for Type B and C packages the former encompasses test methods appropriate for Industrial and Type A Packages.

6.8. Test Substitution

SSG-26 Para. 701 states that demonstration of compliance with the performance standards of the regulations shall be accomplished by any of the following methods or by a combination thereof:

(a) Performance of tests with prototypes or samples of the packaging with simulated contents.

(b) Reference to previous satisfactory demonstrations of a sufficiently similar nature.

(c) Performance of scale model tests.

(d) Calculation or reasoned argument, when the calculation procedures and parameters are generally agreed to be reliable or conservative.

This document is mainly concerned with testing using prototypes or samples of the packaging.

SSG-26 Para. 701.11 states:

In considering reference to previously satisfactory demonstrations of a similar nature, all the similarities and the differences between two packages should be considered. The areas of difference may require modification of the results of the demonstration. The ways and the extent to which the differences and similarities will qualify the results from the previous demonstration depend upon their effects. In an extreme case, a packaging may be geometrically identical with that used in an approved package but because of material changes in the new packaging, the reference to the previous demonstration would not be relevant and hence should not be used.

It is a common practice to refer to the testing of similar packages to avoid the need for testing of a new or revised package design. This would apply particularly to small changes in the design of a package where it can be demonstrated that such changes will not have a detrimental effect on the performance of the package during testing. This can apply particularly to the penetration test where the features are similar even if the overall package design is significantly different.

Scale model testing is not usually used for Type IP-2, IP-3 or Type A packages. It is mainly applicable to the more expensive, large or complex Competent Authority approved package designs. The use of scale models is a specialist area and if required expert advice should be sought.

Calculation will often require the use of Finite Element Analysis (FEA) to demonstrate the performance of a package during testing. Advice on the application of FEA can be found in TCSC 1087 (reference 15). This is not typically applied to Type IP-2, IP-3 or Type A packages. Exceptions to this are large packages used for waste disposal and storage.

Fairly simple calculations may negate the need for the stacking test and reasoned argument may prove that a penetration test is not required.

7. Pass/ Fail Criteria

For Type IP-2, Type IP-3 and Type A Packages the requirements are that if a package were subjected to the specified tests it would prevent:

(a) Loss or dispersal of the radioactive contents;

(b) More than a 20% increase in the maximum radiation level at any external surface of the package.

Only requirement (a) applies for the additional 9m drop test required for Type A Packages with liquid or gaseous contents.

For Packages containing fissile material excepted by para 674(b), the package, after being subjected to the tests specified in paras 719–724 would:

- Retain its fissile material contents;
- Preserve the minimum overall outside dimensions of the package to at least 30 cm;
- Prevent the entry of a 10 cm cube.

These are now considered in more detail.

7.1. Loss or Dispersal of Contents

SSG-26 Para . 624.1.

Consideration of the release of contents from Type IP-2 packages imposes a containment function on the package for normal conditions of transport. Some simplification in demonstrating no loss or dispersal of contents is possible owing to the rather immobile character of some LSA material and SCO contents and the limited specific activity and surface contamination. See also paras 648.2–648.5.

SSG-26 Para . 648.2 notes that a maximum allowable leakage rate for the normal transport of Type A packages has never been defined quantitatively in the Transport Regulations but it has always been required in a practical sense and para. 648.3 states that the intent of this testing is to ensure that under normal transport conditions the radioactive contents of the package cannot escape in quantities that may create a radiological or contamination hazard. This appears at odds with the Regulations which state specifically that there shall be no loss or dispersal of the radioactive contents. Although a small leakage may not create a significant radiological hazard (as accepted for Type B Packages), the Regulations are quite specific.

This requirement of the regulations must be complied with. However, since it is not practical to prove absolutely no loss of contents, visual observation of loss of solid or liquid contents following testing is the accepted practical method. For solid payloads fluorescent dust may be added to the payload. Any leakage from the package will be obvious when examined under ultra violet light. Similarly dye may be added to liquid packages.

Where a leakage rate for an IP-2, IP-3 or Type A can be quantified it is accepted practice to apply the equivalent numerical criterion for a Type B package. That is to restrict the loss of radioactive contents to not more than $10^{-6}A_2$ per hour. More generally a leakage rate cannot be quantified and a qualitative method must be used.

When testing combination packages incorporating a separate inner packaging, the requirement remains that there should be no loss or dispersal of radioactive contents from the package. Leakage from the inner packaging which is contained within the outer packaging following a drop test would not constitute a failure provided the contents are retained by the outer packaging. Puncturing of the outer packaging during the penetration test is acceptable providing there is no loss of contents.

For Type A packages containing liquids, incorporating a primary and secondary containment, it will be necessary to demonstrate that there has been no leakage of liquid from the secondary outer containment. A typical design of this type is a radiopharmaceutical package where a vial or syringe forms the primary inner containment which is carried in a sealed secondary containment vessel. No loss of liquid can be demonstrated by visual inspection with dye added to the liquid. It may be beneficial to place tissue paper around the secondary containment so that any leakage is more obvious although this must not interfere with the behaviour of the package during testing.

For packages containing gases it is not so simple to demonstrate that there has been no loss of contents. Other methods would need to be adopted such as no loss of pressure following testing or by very accurately weighing the gas receptacle before and after testing.

7.2. Radiation Level

SSG-26 Para. 624.4.

For packages exhibiting little external deformation and negligible internal movement of the radioactive contents or shielding, a careful visual examination may provide sufficient assurance that the surface radiation level is essentially unchanged.

For unshielded packages, radiation levels will increase either because the contents have moved during testing so they are closer to the surface of the package or because the surface has been damaged moving it closer to the contents. For packages incorporating shielding, movement or damage to the shielding may also increase radiation levels. For most package designs, post-test visual examination will demonstrate that there has been little movement of the contents so no increase in radiation levels would be expected. Damage to the surface may be so small that it is obvious that there would not be a 20% increase in radiation level. If there is significant damage, it may be necessary to assess and calculate what effect this would have on radiation levels. For shielded package designs, significant movement or damage to the shielding would have to be assessed. This may require destructive examination of the package or containment to determine whether for example poured concrete shielding has cracked or its effectiveness reduced during testing.

SSG-26 Para. 624.5.

If it is considered that the maximum surface radiation level has increased, monitoring tests should be performed to confirm this.

This would involve placing a radioactive test source inside the package and measuring surface radiation levels before and after testing (the source would be removed during testing). The subsequent paragraphs in SSG-26 consider this in more detail and should be referred to if necessary.

It should be noted that the 20% increase applies irrespective of the actual radiation level. Even if the radiation levels are low, as may well be the case for an IP-2 package and the radiation level following testing is within the allowable surface radiation limit of 2 mSv/h (non exclusive use) the 20% limit applies. e.g. if the maximum surface radiation level prior to testing is 0.1 mSv/h, the maximum following testing must be less than 0.12 mSv/h.

7.3. Packages Containing Fissile Material Expected By Para 674(b)

As with the prevention of loss or dispersal criterion, the retention of fissile material contents criterion is absolute. It is not practical to prove absolutely no loss of contents. Additionally the criterion to retain fissile material contents is a less stringent standard than prevent loss or dispersal of the radioactive contents as a release of radioactive contents that would be considered significant for radiological safety may be insignificant in respect of criticality safety. The standard and can be considered to be met if less than 0.25g of fissile nuclides would be lost from the packaging (see paragraph 5.5.2 of reference 17 Application of the Revised Provisions for Transport of Fissile Material in the IAEA Regulations for the Safe Transport of Radioactive Material 2012 Edition (IAEA-TECDOC-1768).

Testing to paragraphs 721-724 for IP-3 and Type A packages to demonstrate prevention of loss or dispersal of contents bounds the retention of fissile material contents and prevent the entry of a 10 cm cube criteria. For IP-2 packages the additional effects of paragraph 721 and 724 must be considered. Furthermore for IP-2 packages approved to the alternative requirements in paragraphs 626-630 then the tests in paragraph 721-724 will need to be addressed in addition to the alternative test requirements.

The criteria to preserve the minimum overall outside dimensions of the package to at least 30 cm ensures that the minimum possible pitch of packages in an array remains safely subcritical. The criterion is met if each of the package outer dimensions (height, width, length or diameter) following the tests in paragraph 721-724 is at least 30 cm, taking account of any knockback or other deformation.

8. Test Plan

A Test Plan or Test Specification should be prepared specifying the test requirements. The complexity of the plan should reflect the complexity of the package and the test requirements.

It is essential that all stakeholders i.e. approval authority, test house staff, and designers discuss and agree the test plan.

Additionally responsibilities should be carefully defined e.g. who prepares the specimens; who is responsible for lifting equipment and where interfaces are identified has the required data been distributed to all parties.

The Test Plan may include the following sections:

- **Front Sheet**

Title, document reference and issue status, including signatures of the author, and to note the document has been subject to verification.

- **Introduction**

This section provides background to the tests, introduces the package and outlines the relevant regulatory test requirements.

- **Objectives**

This section states the objectives of the tests.

- **Test Specimen**

This section should provide a detailed specification for the test specimen(s) usually by reference to drawing numbers or a full specification for proprietary items. It should include a detailed specification of the contents.

- **Test Requirements**

This section specifies which tests are to be performed and details specific requirements for these tests. This may include the stacking test load and details of how it should be applied, drop test height(s) and specimen orientation(s), drop test target details, penetration test drop height(s) and point(s) of impact. It will define how many specimens should be tested and which tests they will subject to.

This section will include any special requirements regarding temperature, pressure, etc.

- **Test Procedure**

This section details the test procedure and may include the following sections:

a) Preparation of test specimen

Including pre-assembly inspection and leak testing if required.

b) Loading of simulated contents

Details of simulated contents, required gross mass of specimen.

c) Assembly of specimen

This may include a detailed assembly procedure so that the specimen tested matches the actual package as far as possible (bolt torques, etc).

d) Post assembly inspection

This will specify inspection and leak testing requirements and should ensure that the specimen and test area are clean so that any leakage can be observed.

e) Test schedule

Which specimens are to be subjected to which tests in what order. May include lifting and handling instructions if specific requirements apply.

f) Post test inspection

Inspection of specimen and test area for leakage, external visual inspection of specimen and measurement of damage, strip down and internal examination and measurement of damage to internal components or leakage from internal containment/receptacles. The use of complex measuring equipment is not normally required for Type IP-2, IP-3 or Type A, simple tape or rule measurements are sufficient. Post test inspection may include leak testing of the package or components.

g) Photo/video requirements

Typically photos at every stage. Digital video of drop tests is usually included but high speed video is not generally specified for Type IP-2, IP-3 or Type A packages.

- **Instrumentation and data processing**

Where appropriate, details of instrumentation such as accelerometers, strain gauges, etc and associated instrumentation. This is not normally required for Type IP-2, IP-3 or Type A.

- **Reports**

This section defines the extent, scope and format of reporting required.

- **Quality Assurance**

This section defines the Quality Assurance requirements.

The test station will typically be required to prepare and submit a testing quality plan covering all aspects of the test programme. It may include hold points for third party/customer inspection/witnessing.

The test station facilities must satisfy the regulatory requirements as outlined in this document e.g. the drop test plate must be of sufficient size and mass, the penetration bar must have the correct dimensions etc.

This section will specify any approval requirements applicable to the test station. There are no regulatory requirements for the approval or accreditation of test stations for radioactive material packages. Note that tests for UN package approval can only be performed by authorised test stations accredited by the United Kingdom Accreditation Service (UKAS).

- **Safety**

This section defines the safety measures that must be observed which may include limiting access to the test area, personnel protective equipment, etc. A risk assessment should be performed to determine what safety measures are required.

Of key importance is the handling and controlled release of the test specimen. A premature release may be inconvenient at best and potentially dangerous if personnel are still near the package, drop test mechanisms should always fail safe.

Particular care must be taken when testing packages containing pressurised gases which can be subject to explosive failure. It may be advisable to undertake an initial test in the unpressurised state so that the probable behaviour when pressurised can be assessed.

9. Preparation of Test Specimen

9.1. Pre-test Inspection

All components of the test specimen should be thoroughly inspected prior to assembly to ensure they comply fully with the specification and there are no:

- Defects that may have occurred during manufacture.
- Corrosion or other deterioration.
- Defects in the closing mechanism.
- Defects or damage to seals.
- Any other deviation from the specified design.

Checks may include:

- Dimensional survey to confirm compliance with the specification and so that any subsequent damage can be assessed.

- Weight of components.
- Check of QA records to ensure that the correct materials have been used (including seals and fasteners).
- NDT testing of manufactured components.

9.2. Assembly

Detailed assembly instructions should be available to ensure that the build of the test specimen corresponds to the assembly activities of the operating and handling instructions for the package design.

Detailed records should be kept of assembly and the test specimen configuration. Photographs should be taken at each stage of the test specimen preparation and the weight of each component and assembly before and after filling should be recorded.

A dimensional survey of the assembled specimen should be undertaken so that subsequent damage can be assessed.

9.3. Leak Testing

If required the package or containment shall be leak tested. Advice on the leak testing of packages can be found in TCSC 1068 (reference 14).

9.4. Pre-conditioning (Positive/ Negative Pressure)

Pre-conditioning may be required if the packaging is expected to suffer some degradation in mechanical properties due to handling. For example a Type A disposable package may need to be subjected to a simulation of rough handling so that it can be demonstrated during testing that the specimen is representative of the in-service item.

Should the containment system rely on the expansion/contraction of wrapping materials it may be prudent to run several pressurisation/depressurisation cycles to ensure that chafing or stretching does not adversely affect the materials.

9.5. Divergence/ Deviations from Specification

All deviations from the specification shall be recorded. Any deviation must be justified as having no effect on the outcome of the test or must be incorporated into the production package design or instructions.

10. Testing

10.1. General Requirements

The tests shall be supervised by a Suitably Qualified and Experienced Personnel (SQEP), who must ensure that the requirements of the Test Plan are carried out precisely.

All slinging and lifting operations shall be undertaken using suitable certified equipment, operated by appropriate Suitably Qualified and Experienced Personnel (SQEP).

Suitable safety measures as specified in the Test Plan, such as barriers to control access to the test site shall be implemented and suitable personnel protective equipment (e.g. hard-hats, safety shoes, safety glasses, gloves) shall be worn.

The test engineer shall ensure that all measuring and recording equipment works correctly, that all instruments are properly calibrated, and that the test/calibration certificates are available and valid for the duration of the tests.

If the test specimen has been transported prior to testing or was assembled some time prior to testing, it shall be inspected before any testing takes place to ensure that it is in good condition, i.e. that it has not deteriorated or been damaged between completion of manufacture and reaching the test site.

10.2. Testing

The tests shall be performed in accordance with the Test Plan.

It is acceptable to deviate from the Test Plan if necessary by agreement with the client or Design/Approval Authority as appropriate. All deviations must be recorded.

10.3. Post-test Inspection

After each test the specimen shall be examined for leakage and details of all damage shall be recorded. This will usually require a dimensional survey of the damaged specimen. Following drop tests the target plate shall be examined for evidence of leakage from the package.

10.4. Leakage Testing

If required the package or containment system shall be leak tested. Advice on the leakage tests of industrial and Type A packages can be found in TCSC 1068 (reference 14).

If a series of tests are being performed on a single specimen it is advisable to undertake leakage tests on the specimen after each test to ensure that performance of the specimen is compliant with the design specification prior to each test.

10.5. Third Party Witness

There is no regulatory requirement for specific third party witnessing of the regulatory testing of Type IP-2, IP-3 or Type A Packages. There may be a requirement for proof testing of pressure vessels or lifting points to be witnessed depending on site requirements.

The Design/Approval Authority and/or the client may wish to witness testing and undertake their own checks. They should be given timely notice of the testing arrangements and suitable arrangements should be made to accommodate them.

11. Reporting Results

On completion of testing the results must be recorded and reported. The resultant test report will typically be referenced in the Package Design Safety Report to demonstrate compliance with the regulatory test requirements. The style and format of the report should reflect the complexity of the package design. For simple package constructions, e.g. single use fibreboard box style packages, a pro-forma format supported by still photographs and test data may be adequate. For complex package constructions, that may be large and costly, a more lengthy and detailed written report would be more appropriate.

Written test reports may be organised, as far as practical and appropriate for the package design as follows:

- Title, document or test reference.
- Signatures, including signatures of the author, and to note the document has been subject to verification.
- Introduction.
- Scope.

- Test type, to include test procedure reference and pass/fail criteria.
- Details of test specimen used for testing with reference to specification and QA inspection.
- Test equipment, calibration certificates, serial numbers of measurement tools and test equipment used.
- Test results, to include nature of damage sustained, containment and shielding assessment.
- Deviations, from test plan.
- Conclusions/Recommendations (if appropriate and required).
- Attachments, photographs, video references where appropriate, record sheets made at time of testing.

12. References

1. INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Standards, Regulations for the Safe Transport of Radioactive Material, Specific Safety Requirements, No. SSR-6 2012 Edition.
2. INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Standards, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Specific Safety Requirements, No. SSG-26 2012 Edition
3. TRANSPORT CONTAINER STANDARDISATION COMMITTEE, Self-Assessment and Approval of Package types IP-1, IP-2, IP-3 and Type A. TCSC 1078
4. TRANSPORT CONTAINER STANDARDISATION COMMITTEE, Good Practice Guide to Drop Testing of Type B Transport Packages, TCSC 1089
5. TRANSPORT CONTAINER STANDARDISATION COMMITTEE, The Design, Manufacture, Approval and Operation of an ISO Freight Container for use as an Industrial Package Type 2 (IP-2), TCSC 1090
6. UNITED NATIONS, Recommendations on the Transport of Dangerous Goods – Model Regulations, Nineteenth Revised Edition ST/SG/AC,10/1/Rev.19, 2015
7. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Series 1 freight containers - Specification and testing, Part 3: Tank containers for liquids, gases and pressurized dry bulk, ISO 1496-3:1995
8. UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE (UNECE), European Agreement Concerning the International Carriage of Dangerous Goods by Road, ADR 2017 Edition
9. INTERGOVERNMENTAL ORGANIZATION FOR INTERNATIONAL CARRIAGE BY RAIL (OTIF), Regulations Concerning the International Carriage of Dangerous Goods by Rail, RID 2017 Edition
10. INTERNATIONAL MARITIME ORGANIZATION (IMO), International Maritime Dangerous Goods (IMDG) Code, 2016 Edition (Amdt. 38-16)
11. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Series 1 freight containers - Specification and testing, Part 1: General cargo containers for general purposes, ISO 1496-1:2013
12. CSC 2014 edition, International Convention for Safe Containers, 1972. International Maritime Organisation, sixth edition, 2014
13. OFFICE FOR NUCLEAR REGULATION, A DfT Guide to the Approval of Freight Containers as Type IP-2 and Type IP-3 Packages. DfT/RMTD/0002 (Freight Containers), Issue 2, July 2005
14. TRANSPORT CONTAINER STANDARDISATION COMMITTEE, Leakage Tests on Packages for Transport of Radioactive Materials, TCSC 1068
15. TRANSPORT CONTAINER STANDARDISATION COMMITTEE, Good Practice Guide - The Application of Finite Element Analysis to Demonstrate Impact Performance of Transport Package Designs, TCSC 1087
16. ISO 12807:1996(EN) Safe transport of radioactive materials — Leakage testing on packages
17. Application of the Revised Provisions for Transport of Fissile Material in the IAEA, Regulations for the Safe Transport of Radioactive Material 2012 Edition (IAEA-TECDOC-1768)