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TCSC

Transport Container Standardisation Committee

Transport of Radioactive Material Code of Practice

The Design, Manufacture, Approval and Operation of an ISO Freight Container for Use as an Industrial Package type 2 (IP-2)

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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Comments and suggestions relating to the improvement of this Code of Practice should be addressed to the TCSC Secretariat at admin@tcsc.org.uk.

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CONTENTS

Foreword

Freight containers provide a standardised, cost effective and convenient method of handling and transporting goods. They are specifically designed to facilitate the carriage of goods by one or more modes of transport, without the need for intermediate reloading. They are generally of all welded steel construction and incorporate standard features to facilitate tie-down during transport and handling during inter-modal transfers.

The IAEA Regulations for the Safe Transport of Radioactive Material, Specific Safety Requirements No SSR-6, permits the use of freight containers for transporting certain categories of radioactive material provided that a number of specific requirements are complied with.

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

This document represents good practice and takes the form of recommendations to achieve compliance with the Regulations for the Safe Transport of Radioactive Material. 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. To conform to this document, all operations shall be performed in accordance with its requirements, but not necessarily with its recommendations.

1. General

1.1. Scope

This Code of Practice gives guidance on the requirements for the design, manufacture, testing, approval, operation and maintenance of ISO freight containers for use as Industrial Packages Type 2 (IP-2), which are appropriate for their intended use whilst satisfying the requirements of the IAEA Regulations for the Safe Transport of Radioactive Material (Ref. 1).

The requirements of the IAEA regulations (Ref. 1) are followed and referenced where appropriate by the relevant paragraph number quoted in square brackets [ ].

1.2. Definitions

ACEP. Approved Continuous Examination Programme in compliance with the International Convention for Safe Containers (CSC) (Ref. 16).

Approval Authority. An organisation or an individual responsible for the approval of Industrial Type 2 package designs as delegated by the Competent Authority.

Certificate of Approval (Approval Certificate). Certificate of Approval means a certificate issued by an Approval Authority signifying that the package design fulfils the requirements of the applicable regulations.

Competent Authority. Any national or international regulatory body or authority designated or otherwise recognised as such for any purpose in connection with the Regulations. In Great Britain, the Office of Nuclear Regulation (ONR) is the Competent Authority for civil inland surface transport and associated package licensing applications, ONR also acts on behalf of the Maritime and Coastguard Agency (for sea transport) and the Civil Aviation Authority (for air transport). In Northern Ireland, the Department of the Environment for Northern Ireland is the Competent Authority for civilian road transport.

For UK defence related package licensing applications, the Competent Authority is the Defence Nuclear Safety Regulator (DNSR).

Containment System. The assembly of components of the packaging specified by the designer as intended to retain the radioactive material during transport.

CSC. (International) Convention for Safe Containers (Ref. 16).

Design Number. A number assigned to a specific packaging design, described in TCSC 1073 (Ref. 15).

Exclusive Use. The sole use, by a single consignor, of a conveyance or of a large freight container, in respect of which all initial, intermediate and final loading and unloading and shipment is carried out in accordance with the directions of the consignor or consignee [221].

Freight Container. An article of transport equipment that is of a permanent character and accordingly strong enough to be suitable for repeated use; specifically designed to facilitate the transport of goods, by one or more modes of transport, without intermediate reloading, designed to be secured and/or readily handled, having fittings for these purposes. The term *"freight container"* does not include the *vehicle*. A *small freight container* shall mean a freight container that has an internal volume of not more than 3 m^3. A large freight container shall mean a freight container that has an internal volume of more than 3 m^3 [223].

Gauge Capability Number. The Gauge Capability Number (also known as the Loading Gauge Capability Number) relates to the height and width profiles which govern the

physical dimensions of a railway vehicle and its load that can be used on a specific route to ensure that the vehicle will not come into contact with trackside or over-line structures.

HSE. Health and Safety Executive.

Industrial Package. A packaging, tank or freight container containing Low Specific Activity (LSA) material or a Surface Contaminated Object (SCO).

IP-2. Industrial Package Type 2.

IPR. Intellectual Property Rights.

ISO. International Standards Organisation.

LSA. Low Specific Activity – Radioactive material that by its nature has a limited specific activity, or radioactive material for which limits of estimated average specific activity apply [226].

Management System. A set of interrelated or interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective manner.

Package Design Safety Report. A Package Design Safety Report provides the documentary evidence of the compliance of the package design with all the applicable requirements.

PES. Periodic Examination Scheme – an approved examination scheme in compliance with the International Convention for Safe Containers (CSC).

RMT. Radioactive Material Transport.

Regulations. As used throughout this document are defined as IAEA Specific Safety Requirements No. SSR-6, Regulations for the Safe Transport of Radioactive Material, (Ref. 1). It should be noted that the requirements of other National and/or modal regulations also may apply and need to be considered.

Route Availability Number. The Route Availability Number is the system which determines which types of railway locomotive and rolling stock can travel over any particular route. It is used to determine the compatibility of the weight of rail vehicles with the strength of underline structures. The Route Availability Number assigned to a railway vehicle is derived from its maximum axle loads and axle spacing, whereas the Route Availability Number for a railway route is derived mainly from the strength of underline structures.

Routine Conditions of Transport. For the purposes of this document the Routine Conditions of Transport are as defined in TCSC 1006 (Ref. 14).

SCO. Surface Contaminated Object – a solid object that is not itself radioactive but which has radioactive material distributed on its surface [241].

SLR. Standardised Leak Rate (Ref. 13).

2. Regulatory Requirements

2.1. Introduction

The packaging standard given in the regulations for Type IP-2 packages is a basic packaging standard which requires packages to be shown to provide no loss or dispersal of contents and a limited increase in radiation levels if the package is subjected to drop and stacking tests appropriate to normal conditions of transport

The regulations also permit acceptable alternative packages to be used as Type IP-2 and IP-3, where they incorporate sufficient safeguards to ensure equivalence for compliance

against the required regulatory drop and stacking tests. These alternative packages include; UN tested packages, tank containers, tanks, freight containers and metal intermediate bulk containers (IBC's).

The reason these alternative packages are include in the regulation is that it is unnecessary to carry out additional tests where:

1. Alternative tests are essentially the same as the regulatory tests (e.g. for UN drums and metal IBC's). or;
2. It is deemed to be more appropriate to use the alternative requirements (e.g. for tank containers, tanks and freight containers).

2.2. Standard Requirements

The alternative requirements for freight containers specified in paragraph [629] of the regulations are:

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

1. The radioactive contents are restricted to solid materials:
2. They satisfy the requirements for Type IP-1 specified in para. 623:
3. They are designed to conform to the standards prescribed in 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 the accelerations
   a) Loss or dispersal of the radioactive contents; and
   b) More than a 20% increase in the maximum radiation level at any external surface of the freight containers.

The IAEA advisory material, SSG-26 (Ref. 2), provides the following advice on the adoption of the alternative requirements for freight containers:

629.2. 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. Consideration should be given to the construction details of the container to ensure that the containment requirements can be met. For example, welded joints are easier to test for leakage if they are visible. Only closed types of freight container can be used to demonstrate compliance with the Type IP-2 and Type IP-3 containment requirement of no loss or dispersal of radioactive contents and monitoring during and after testing is necessary to demonstrate this.

629.3. Freight containers should be able to demonstrate their capability to retain and contain their contents during accelerations occurring in routine transport because ISO standard tests for freight containers do not include dynamic tests. In practice, this may require demonstration of containment at the following stages, taking into account the contents to be transported:

1. Prototype testing to ISO 1496 tests (before application of test loads, when the container is statically loaded, and when the test loads have been removed);
2. Production of each unit;
3. Maintenance;

3. Design

3.1. Introduction

To comply with the regulatory requirements [629], freight containers must be designed to conform to the standards prescribed in ISO 1496/1 (Ref. 3) (excluding dimensions and ratings) and be designed such that if subjected to the tests prescribed in ISO 1496/1 and the accelerations occurring during routine conditions of transport they would prevent loss or dispersal of the radioactive contents and more than a 20% increase in the maximum radiation level at any external surface of the freight container

ISO 1496/1 (Ref. 3) specifies the basic specifications and testing requirements for series 1 ISO freight containers of the totally enclosed general purpose type. Although ISO 1496/1 lists the design requirements and specifies test loads and loadings that the container shall be capable of withstanding under the specified test requirements, it does not specify design stresses.

The acceptance requirement specified in ISO 1496/1 for each load test is:

Upon completion of the test, the container shall show neither permanent deformation which will render it unsuitable for use nor abnormality which will render it unsuitable for use, and the dimensional requirements affecting handling, securing and interchange shall be satisfied". This effectively allows localised stresses under test loads to exceed yield stress in some circumstances. To take full advantage of this, ISO freight container manufacturers use their own in-house design standards to keep tare weights to a minimum whilst maximising payload capacity. In practice, it is not unknown for a few millimetres of permanent set recorded under container type approval (prototype) testing to be accepted by the third party ISO approved inspection body provided the overall dimensions remain within the permitted tolerances.

3.2. Package Rating and Dimensions

To determine the package rating and overall dimensions the designer must consider the following:

a) mass, form and dimensions of the proposed payload to be consigned. Consideration shall be given to the payload distribution within the package to ensure that the centre of gravity is kept as near central and as low as possible;

b) Plant interfaces, e.g. crane capacity, plant access, etc. at both the consigning and receiving facilities and any inter-modal transport interchanges need to be assessed to identify any potential interface issues, such as handling capacities; and

c) Modes of transport to be employed and routes. The package rating and dimensions may rule out specific modes of transport and routes, e.g. exceeds the rail gauge capability, exceeds permissible road axle weights, etc.

Although the IAEA regulations (Ref. 1) require conformance to the standards prescribed in ISO 1496/1 (Ref. 3) for this type of package they specifically exclude the requirement to conform to the ISO dimensions and ratings.

It should be noted that the use of different dimensions and ratings to those specified in BS ISO 668 (Ref. 4) requires careful consideration, especially with respect to tie-down and handling of the package, as this will impact on the transport interface.

3.3. Retention for Non-standard Packages

For road and rail transport tie-down of the package is usually via twistlocks, which are normally an integral part of the conveyance, engaging in the bottom corner fittings/castings.

If the dimensions of the container are to differ from standard, consideration should be given to maintaining the positions of the bottom corner fittings at the ISO specified centre distances. Where this is not possible an adapter stillage may be required to effect tie down of the package to the conveyance. A similar driver exists for maintaining the top corner fittings/castings at the ISO specified centre distances to enable the use of ISO standard lifting spreader frames without the need to resort to developing and deploying package specific lifting equipment.

Ships designed to transport ISO freight containers incorporate structures, fittings and guides which are used to position and hold containers. Such features are designed to accommodate containers conforming to the standard ISO dimensions and ratings. Therefore, deviating from the standard dimensions and ratings may preclude transport by sea on general commercial freight liners.

Deviating from the ISO dimensions and ratings could prove problematic at ports and rail freight terminals where the freight container handling infrastructure is generally sized to accommodate freight containers conforming to the standard ISO dimensions and ratings. Similarly, deviating from the ISO dimensions and ratings may prove to be problematic when stacking containers at inter-modal interchanges.

3.4. Radioactive Contents and Form

The regulations restrict the contents to be carried in this type of package to solid form because they are not regarded as being suitable for free liquids or liquids in non-qualified packaging. Therefore, no free liquids or gases are permitted unless they have been irreversibly absorbed within a solid.

Table 1 provides a correlation between Industrial Package type and the permitted material classification that can be consigned. Reference should be made to the regulations for further guidance on permitted contents for this type of package.

Table 1: Industrial Package Requirements for LSA Material in Solid Form and SCO

Contents (Solid Form)	Industrial Package Type	
	Exclusive Use	Non-exclusive Use
LSA-II	Type IP-2	Type IP-2
LSA-III	Type IP-2	Type IP-3
SCO-II	Type IP-2	Type IP-2

NOTE: Freight containers, when used as packaging rather than overpacks, are usually transported under exclusive use so Type IP-3 is rarely required.

A freight container can be consigned for transport under exclusive use, provided the closures are secured and remain so throughout shipment, irrespective of the number of packages on a conveyance.

3.5. Transport Routes, Modes of Transport and Types of Conveyance

General

Commercial ISO freight containers are truly inter-modal and are used for all three modes of surface transport i.e. road, rail and sea. However the transport infrastructure will generally be sized for containers conforming to the standard ISO dimensions and ratings.

Road Transport

Within the UK, the maximum gross vehicle weight for road transport permitted under the Construction and Use Regulations (Ref. 5) is 44 tonnes and the maximum vehicle width is 2.55 metres. Typically, vehicles used to transport ISO freight containers utilise lightweight skeletal trailers which are designed to transport freight containers conforming to the standard dimensions and ratings without exceeding the maximum permitted gross vehicle weight.

Wider loads up to a maximum of 4.3 metres can be transported as an abnormal indivisible load under the Construction and Use Regulations. It is also possible to transport heavier loads, where the maximum gross vehicle weight would exceed 44 tonnes, as an abnormal indivisible load under the Road Vehicles (Authorisation of Special Types) (General) Order 2003 (Ref. 6) which permits the use of certain vehicles which do not fully comply with the Construction and Use Regulations (Ref 5). However, in each case, the consignor must ensure that the load to be transported truly conforms to the definition of an abnormal indivisible load: "*A load which cannot without undue expense or risk of damage be divided into two or more loads"*.

Rail Transport

Within the UK, railway routes are assigned a (loading) Gauge Capability Number and a Route Availability Number. Generally, the standard ISO freight container dimensions are unlikely to challenge the Gauge Capability except for those containers known as the 'high cube' type which are 9′ 6″ (2895 mm) high. Although this type of container is becoming more common within the commercial freight container arena there is currently very limited Gauge Capability for such containers on the UK rail network.

Similarly, the standard ISO freight container ratings are unlikely to challenge the Route Availability on the UK rail network since the load capacity for rail is generally higher than road transport limits; however an increase in the maximum gross rating of an ISO freight container may rule out its use on some branch line routes.

ISO freight containers which do not comply with the standard dimensions or gross mass ratings may require bespoke rolling stock.

Sea Transport

The transport of ISO freight containers by sea is usually carried using either purpose designed ships which incorporate structures, fittings and guides which are used to position and hold containers, or; roll-on/roll-off ferry ships that are designed to carry wheeled cargo where the containers remain attached to the road trailer (or rail wagon) on board ship. Further guidance on the tie-down and retention of vehicles carrying freight containers on roll-on/roll-off ferry ships is provided by the International Maritime Organisation (Ref. 7).

3.6. Shielding

The regulatory requirements for LSA and SCO are that the external radiation level at 3m from the unshielded material shall not exceed 10 mSv/hr [522].

The conventional ISO freight structure provides negligible radiation shielding benefit. Where shielding is an identified requirement for this type of package it can generally be included as an integral part of the payload to ensure compliance with the regulatory limits on radiation levels at the surface of the package [527] [528] [617] although the casting of concrete slabs into the container structure can be used to provide integral shielding. These regulatory limits vary depending on whether the package is to be used under exclusive use or non-exclusive use; however, the higher surface radiation limit permitted under exclusive use places further restrictions on the conveyance [573], which need to be considered.

3.7. Materials

General

To comply with the regulations (Ref. 1) the properties of the materials used for the package construction need to be generally constant across the required operating temperature range. However, unlike some other package types for which the regulations specify a temperature range of -40°C to +70°C, the regulatory requirement specified for Type IP-2 packages is: "*The design of the package shall take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport"* [616].

The associated advisory material, SSG-26 (Ref. 2), states: "An ambient pressure range of 60–101 kPa and an ambient temperature range of –40 to 38°C are generally acceptable for surface modes of transport. For surface movements of excepted package(s), industrial packages Types IP-1, IP-2 and IP-3, and Type B(M) packages solely within a specified country or solely between specified countries, ambient temperature and pressure conditions other than these may be assumed providing they can be justified and that adequate controls are in place to limit the use of the package(s) to the countries concerned." [616.2]

Therefore, for Type IP-2 packages restricted to use within the UK only, it should be possible to assume less onerous package temperatures and pressure limits with supporting justification. Such justification is usually based on historical meteorological data. For example, it should be possible to relax the lower temperature limit of -40°C with adequate supporting justification, which may include operational controls that restrict the use of the package. This broadens the potential range of materials available to the package designer.

IP-2 packages only need to be tested at an ambient temperature. The designer should consider the effects of the range of ambient temperatures that could be encountered during routine conditions of transport. A packaging material's integrity could be impaired by a temperature that could reasonably foreseeably be encountered during routine conditions of transport. In such cases the designer should specify a safe operating temperature range to exclude the possibility of the package being transported in an unsafe condition.

Carbon Steel

Commercial ISO freight containers are generally fabricated from thin section, press formed, structural carbon steels. This provides good structural strength whilst minimising the tare weight of the package thus maximising payload capacity. However, carbon steels are susceptible to brittle fracture under low temperature conditions. To negate the risk of brittle fracture carbon steel grades with certified cold temperature impact properties must be specified for all carbon steel sections with a section thickness of 6 mm or above: it is generally accepted that such material will not fail in a brittle way if it is less than 6 mm thick and BS EN 10025-1 (Ref. 8) states that impact tests are not required for nominal thicknesses less than 6 mm.

Generally, on commercial freight containers only the corner fittings, which are usually castings, are supplied with certified cold temperature impact properties yet structural carbon steel sections with section thicknesses of 6 mm and above are commonly used for the structural frame. However, for Type IP-2 ISO freight containers to fully comply with the

regulations all structural carbon steel sections with section thicknesses of 6 mm and above must be specified with cold temperature impact properties. This usually takes the form of a Charpy impact value of 27J at a specified lower operating temperature.

Stainless Steel

For Type IP-2 freight containers, a good quality seal is achieved through the use of corrosion resistant austenitic stainless steels for the closure seal faces/seal mounting surfaces.

Wood

Plywood floors are a common feature on commercial ISO freight containers; however such floors should not be fitted to IP-2 freight containers since:

- It is difficult to achieve a satisfactory containment seal,
- They are prone to damage and deterioration,
- Radiologically, wood cannot be effectively decontaminated or monitored hence it is unlikely Health Physics will issue a clearance monitoring certificate. This can also prove problematic when decommissioning the package or clearing the package for alternative use [505].

Elastomers

Three basic elastomer types are commonly used for the closure seals on radioactive material transport packages, namely, Ethylene Propylene Diene Monomer rubber (EPDM), Fluorocarbon rubber (Viton) and Silicone rubber. For each of these basic elastomer types there are numerous commercially available compounds for which the properties can vary significantly. The key properties to be considered when selecting elastomers for closure seals on IP-2 freight containers are hardness, compression set and temperature limits.

The hardness of an elastomer seal is usually expressed in terms of the Shore A durometer scale or the International Rubber Hardness Degrees (IRHD) scale and for most applications a Shore A durometer hardness 70 to 80 is commonly specified. However for an IP-2 freight container, which is a low-pressure application, where the seals are not pressure activated, a lower hardness seal may be more appropriate.

The UK competent authority publishes a useful guide to the suitability of elastomeric seal materials for use in radioactive material transport packages (Ref. 9) which should be consulted.

3.8. Design Life

Consideration should to be given to the design life required of the package along with its expected frequency of use and loading condition.

Commercial ISO freight containers are generally of all fillet weld construction. Such welds offer poor fatigue performance and although BS ISO TR 15070 (Ref. 10) states that “the ISO test loads include a safety factor to account for fatigue, corrosion and damage to which the container may be subjected during its expected operational life”, this safety factor is not quantified and there is no known documented fatigue analysis. For packages that are expected to have a high frequency of use whilst being loaded to or close to the rated maximum consideration should be given to specifying full penetration butt welds for all primary structural welds to improve fatigue performance and prolong the life of the package beyond that of a commercial ISO freight container.

3.9. Decontaminability

Consideration should be given to incorporating features to aid decontamination of the package internals. Typically, examples of such features include strippable surface coatings and stainless steel linings; however the use of stainless steel linings results in an increase in the package tare weight and can complicate leakage testing of the package during manufacture, especially when tracing leak paths.

3.10. Leak Tightness

General

The regulations do not specify a specific level of leak tightness for this type of package, all that is specified is that: “they shall be designed such that if subjected to the tests prescribed in that document (ISO 1496/1) and to the accelerations occurring during routine conditions of transport they would prevent loss or dispersal of the radioactive contents;…..” [629(c)]; therefore, only closed freight containers can be used to demonstrate compliance with this requirement of no loss or dispersal of radioactive contents and monitoring during and after type approval testing is necessary to demonstrate this.

In accordance with the UK Competent Authority guidance DfT/RMTD/0002 (Ref. 11) and para [629.3] of IAEA advisory material SSG-26 (Ref. 2), the prototype package must be shown to be leak tight before, during and after the ISO load tests. This is to ensure that the containment system will remain leak tight during flexing of the body of the ISO freight container, which occurs under routine conditions of transport.

In determining the level of leak tightness required, the form of the radioactive material to be consigned should be taken into account since this can range from large solid objects to fine particulate.

Credit can be taken for any containment provided by suitable inner receptacles, such as UN approved packagings and systems that fix loose contamination.

If a leak test cannot be carried out on a particular package design, alternative procedures shall be developed and justified to the Approval Authority (and the Competent Authority if requested to do so), which should ensure that such procedures meet the requirements of the regulations.

Permissible Leak Rate

The regulations do not specify a permissible leak rate for this type of package. The form and mobility of the radioactive material (which can range from fine powders to bulk solids) to be transported can dictate the level of leak tightness required and the designer should consider this when determining the permissible leak rate for a particular package. The designer will be required to provide supporting detailed justification to justify the proposed leak rate as part of the package licensing submission therefore it should be discussed and agreed with the Approval Authority at the concept design stage (Ref. 12).

Given the relatively large volume of even the smallest ISO freight containers, leak testing can prove to be problematic when using a quantitative method of measuring leak rate due to the low pressures involved: the smallest fluctuations in ambient temperature during the test can have a significant detrimental effect when calculating the SLR. Testing of the body cavity is generally restricted to utilising a qualitative leak test method.

A typical containment leakage test regime for a package of this type used to transport radioactive material in particulate form that meets LSA II criteria consists of:

- A body leakage test comprising of a soapy bubble test of all welded joints with the package internals pressurised to a low pressure, typically 8 to 10 kPa (80 to 100

mbar), which is supplemented by an isolation pressure fall test to ensure no gross leakage has been missed. This test only gives a qualitative result: the absence of air bubbles being indicative of a leak rate of ≤ 1 x10-2 Pa m3 s-1 (1 x10-1 bar cm3 s-1) SLR.

- An interspace test on the double closure seals using an isolation pressure fall method to demonstrate an allowable leakage rate of 1 x10-1 Pa m3 s-1 (1.0 bar cm3 s-1) SLR for the complete seal.

Note: When determining the test pressure to be used for the body leakage test, the designer should compare the test pressure to be applied to the surface area of the walls of the package with the test load to be applied during the ISO side and end wall tests. Where the test pressure loading exceeds the ISO test loads, stiffening jigs will be required to limit the deflections during body leakage testing. A similar requirement may be necessary for the roof (or lid) of the package.

Alternatively, a practical technique can be used to demonstrate the requirement to prevent loss or dispersal of radioactive material during ISO prototype testing. A bright fluorescent powder with a simulated particle size and weight to the anticipated radioactive contents is placed within the package prior to the racking tests, along with a number of electric fans. Once the container door/apertures have been sealed, the fans are switched on to distribute the powder within the sealed container. An ultraviolet light is then used to check for the presence of powder on external surfaces around the container door/apertures. The presence of powder on the external surface would indicate a failure of the containment system.

Although this is not a quantitative method of leak detection, it can be used to demonstrate containment during prototype and routine operational testing providing representative material can be used.

Where the package is to be used solely to transport radioactive material in the form of large solid objects, where there is no potential for loose particulate, a less onerous leakage test may be justifiable. However, the leak rate proposed must be justified and the test methods used must be deterministic as this is the basis of the IAEA regulations (Ref. 1).

Probabilistic methods, such as a statistical approach, should not be used in isolation.

A useful document that may be used to determine leak rate standards and test methods is TCSC 1068 (Ref. 13). However, leak test methods employing vacuum techniques should not be used as the purpose of the leakage test is to demonstrate there is no leakage from the package: a vacuum test would only serve to demonstrate that there was no in leakage.

Where the package is fitted with a filter, the filter must be blanked off for the body leakage test and the test pressure used should take account of the maximum differential pressure the filter is capable of withstanding prior to puncture.

3.11. Elastomer Seals

Elastomeric ‘O’ ring type seals are generally preferred to flat gasket type seals because relatively low compression forces are required to provide a seal. It is common for elastomer seals with a dumbbell type section to be used as the containment seal on packages of this type. This type of seal provides an inbuilt interspace which allows routine quantitative leakage testing of the containment seal to be carried out.

Typically, relatively soft elastomer seals are used with relatively large sections which can accommodate some degree of misalignment due to the fabrication tolerances for the container.

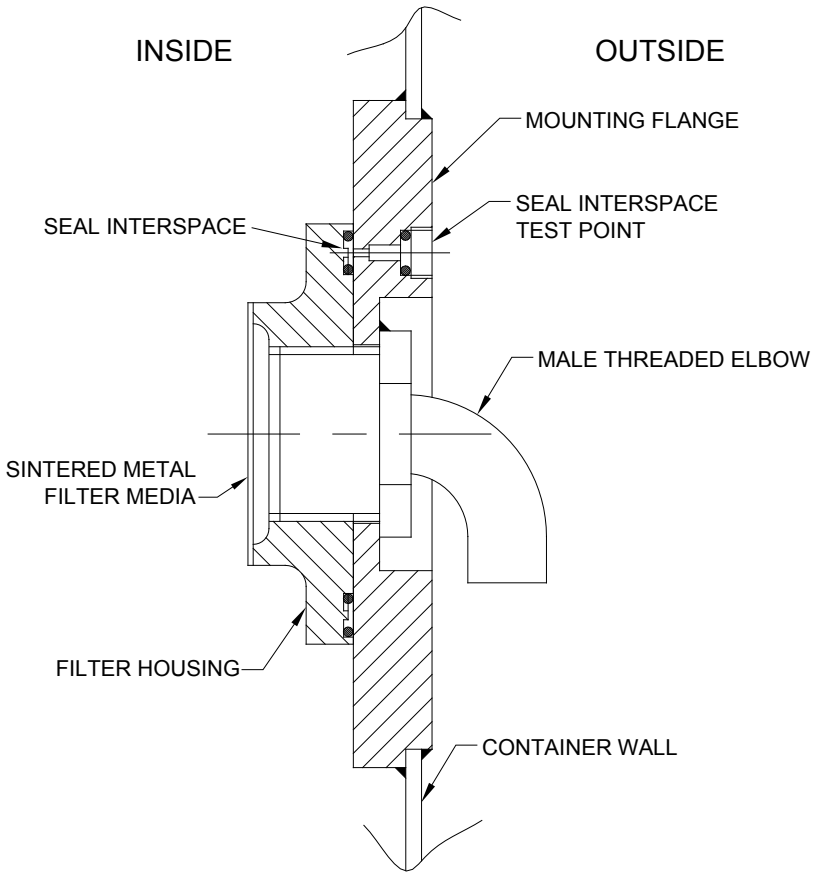
Further guidance can be found in DFT/RMTD/0004 “An applicant’s guide to the suitability of elastomeric seal materials for use in radioactive material transport packages” (Ref. 9).

3.12. Filters

The use of filters to prevent the build-up of pressure inside the freight container due to changes in ambient temperature and barometric pressure is permitted on this type of package but the type of filter and its performance criteria will need to be justified.

Typically, HEPA filters of the stainless steel sintered metal media type shall be used. HEPA filters which utilise paper elements should not be used since they absorb moisture from the atmosphere which ultimately results in the breakdown of the filter element.

Figure 1: Typical HEPA filter arrangement



3.13. Payload Restraint

Although, the ISO type approval test regime for the container walls takes account of the possibility of the payload shifting due to the dynamic accelerations experienced under routine conditions of transport the tests assume that only a fraction of the total payload contacts the container wall and the resulting imposed load is uniformly distributed over the area of the container wall. However, loose bulk items could potentially result in the loading on the walls being unevenly distributed e.g. point loads, which could result in the walls suffering gross deformation exceeding permitted limits or, at worst, being punctured with subsequent loss of containment. Additionally, to be compliant with regulatory requirements [629], freight containers, when subject to accelerations occurring during routine conditions of transport, must not only prevent loss of dispersal of the radioactive contents but they must also prevent more than a 20% increase in the maximum radiation level at any external surface of the package. Therefore, consideration must be given to the method of restraining the payload within the ISO freight container.

Attachments used within ISO freight containers to restrain the payload shall be capable of withstanding the loads typical of routine conditions of transport. They shall be designed to ensure that any movement of the payload will not affect the integrity of the freight container or cause the maximum radiation level at the external surface of the package to increase by more than 20% under routine conditions of transport. This becomes particularly important when the payload is large and/or heavy. If the contents are not tied down using an engineered restraint system, the contents must be packed using inert dunnage to prevent movement of the payload during transport to comply with the regulatory requirements [629].

TCSC 1006 (Ref. 14) gives further guidance on the design of payload restraint systems.

3.14. Marking, Labelling and Placarding

Marking

To comply with the regulatory requirements [531][532][533][534] the package must bear specific markings. The markings must be durable to withstand the rigours of normal conditions of transport, including the effects of weather and abrasion, without any substantial reduction in legibility.

To ensure legibility markings should be boldly printed, of adequate size and sensibly located. Typically, for freight containers, self-adhesive cast vinyl decals using black digits (65 to 100 mm high depending on the specific marking) on a contrasting white background are commonly used. However, freight container walls are usually corrugated and this can affect the legibility of the markings. Therefore consideration should be given, during the design of the package, to providing areas of plain flat surfaces in the wall structures to satisfy the marking requirements for the package but without compromising the structural strength.

The provision of ad hoc boards or plates to carry the markings is not recommended unless they are carefully engineered to ensure that when secured to the package, they do not:

- present hidden moisture traps, which could result in undetected corrosion of the package walls occurring; or
- stand off the wall of the package thus disrupting the ‘clean’ lines of the freight container structure.

If a board or plate is used to carry a marking, it should be fitted securely to the package in a manner consistent with the integrity standard of the package itself.

NOTE: TCSC 1073 (Ref. 15) provides detailed guidance on the marking requirements for packages containing radioactive materials and should be consulted in conjunction with the appropriate national and modal transport regulations.

Labelling and Placarding

The regulations require packages to display labels giving details of the category of the radioactive material being carried [538][539][540]. Typically, the labels usually take the form of pre-printed self-adhesive paper, or plastic, sheet displaying the category of the radioactive material being consigned within the package and they are only displayed when the package contains radioactive material.

In addition to the radioactive material category labels there is also regulatory requirement [543] for large freight containers carrying radioactive material packages (other than excepted packages) to display placards (hazard diamonds) on the external walls of the freight container.

Placards are a larger more rigid form of labelling that is readily visible during transport and these are typically mounted on metal plates which fit into proprietary fixtures, commonly

referred to as placard holders, which must be affixed in a vertical orientation to each side and end wall of the freight container.

Instead of using both placard and category labels the regulations permit the use of enlarged category labels only and this should be the preferred method for all large freight containers.

Additionally, where an exclusive use consignment in a freight container is packaged radioactive materials comprised of a single United Nations Number commodity, the appropriate United Nations Number for the consignment shall also be displayed, either:

- in the lower half of the placard shown in Figure 6 of the regulations, preceded by the letters 'UN' and against the white background; or
- preferably, where enlarged labels are used, on a separate placard (as shown in Figure 7 of the regulations) which is affixed in a horizontal direction immediately adjacent to each of the main placards.

For small freight containers, where placards are not required, placard holders should still be utilised to display the standard category labels as the continual removal and re-application of stick on labels often results in damage to the paint finish of a freight container. The use of stick on labels should be restricted, where possible, to freight containers that are only licensed for single use such as those used to consign low level waste to a repository

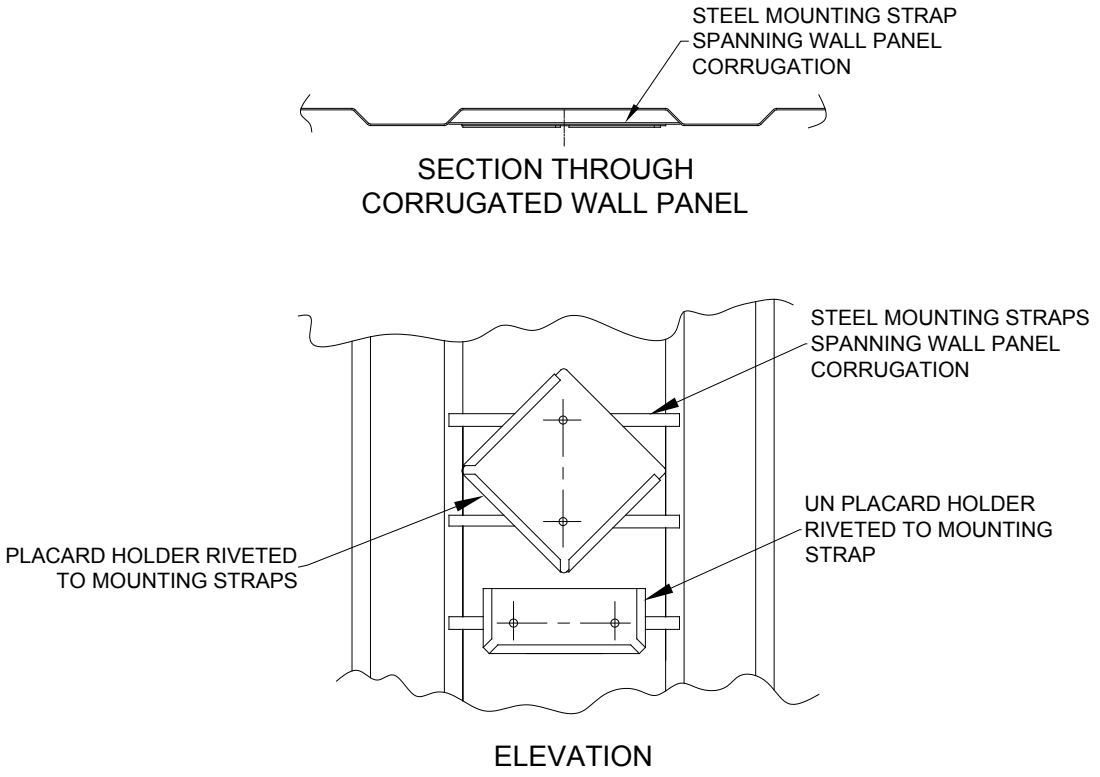
Where placard holders are to be utilised, the package design shall incorporate engineered fixtures for securing the placard holders to the freight container, which ensure they:

- can withstand the rigours of normal conditions of transport;
- do not create hidden moisture traps, which could result in undetected corrosion of the package walls occurring; and
- do not stand off the wall of the package and disrupt the 'clean' lines of the freight container structure.

A common method of mounting placard holders on freight containers is shown in Figure 2

NOTE: TCSC 1073 (Ref. 15) provides detailed guidance on the placarding and labelling requirements for packages containing radioactive materials and should be consulted in conjunction with the appropriate national and modal transport regulations.

Figure 2: Typical placard holder arrangement



3.15. Design Approval

Within the commercial freight container industry, it is not unusual for a prototype container to be manufactured to unapproved drawings with the drawings only being formally approved following successful completion of type approval testing. However, this approach is not regarded as good practice from a quality assurance perspective. Therefore, it is recommended that the drawings should be approved prior to prototype manufacture commencing.

4. Manufacture/Testing

4.1. Manufacture

ISO freight containers are manufactured by specialist manufacturers that are approved under the CSC scheme (Ref. 16). The manufacturer is responsible for obtaining a Type Approval Certificate for each ISO freight container type from an ISO/CSC approved inspection body.

The type approval of the freight container design requires the construction of a prototype container. This prototype shall be constructed using the same Quality Assurance plan, tooling, techniques, materials, weld procedures and methods proposed for production to ensure that the prototype container is representative of all subsequent production units. Only on successful completion of prototype testing can the manufacturer commence production of further containers of that type.

Note: on successful completion of testing, the prototype usually becomes an operational package.

If more than one manufacturer is contracted to produce containers of the same type, each manufacturer is responsible for obtaining a Type Approval Certificate; therefore each manufacturer is required to manufacture a prototype and subject it to type approval (prototype) testing to obtain type approval.

Manufacture shall be carried out under a BS EN ISO 9001 (Ref. 17) compliant quality management system. All manufacturing activities shall be detailed on a manufacturing quality plan.

4.2. Type Approval Testing

Compliance with the ISO 1496/1 (Ref. 3) tests is an accepted alternative to conducting the IAEA regulatory free drop test and stacking test for this type of package.

In order to demonstrate the package design complies with ISO 1496/1 (Ref. 3) a prototype must be manufactured and subjected to the tests specified therein. The tests shall be conducted by an ISO/CSC approved test house and witnessed by an ISO/CSC approved inspection body, as appointed by the Health and Safety Executive (or alternatively by IMO signatory Governments that have ratified, accepted, approved or acceded to the convention), whose attendance is usually arranged by the test house/manufacturer. On successful completion of type approval testing the ISO/CSC approved inspection body will issue a type approval certificate.

The tests specified in ISO 1496-1 are intended to:

- Demonstrate the ability of a container to withstand, without failure of any kind during its service life, the loads encountered under the dynamic and normal operating conditions of various forms of intermodal transportation.
- Simulate the dynamic stresses exerted on containers during the various modes of transportation employed in use.

The ISO 1496/1 type approval tests include a floor strength test to prove the ability of the container floor to withstand the concentrated dynamic loading imposed during loading operations involving powered industrial trucks and the test procedure specifies the load parameters to be applied under test. However, it will be necessary to design the floor to withstand higher loads where the proposed load/truck combination exceeds the load parameters specified in ISO 1496/1, in which case the designer shall specify a higher test load.

In conjunction with the tests specified in ISO 1496/1, containment leakage tests must be conducted to demonstrate the regulatory ‘no loss or dispersal of radioactive contents’ requirement for IP-2 packages. The containment leakage tests are discussed in Section 4.3.

Depending on the method of leak testing employed and the level of leak tightness required, quantitative methods of leak testing can prove problematic if conducted outdoors due to the relatively large volumes and low test pressures involved: the smallest fluctuations in ambient temperature during the test can have a significant detrimental effect when calculating the SLR. Therefore, the use of an indoor ISO test facility is recommended to minimise temperature effects.

The Approval Authority shall be given the opportunity of witnessing the type approval testing. As a minimum they will normally want to witness those tests that are conducted in conjunction with containment leakage testing e.g. the transverse and longitudinal racking (rigidity) tests and, where applicable, the side and end wall loading tests (see Section 4.3 and Ref. 12). It should be noted that:

- The International Convention for Safe Containers (CSC) (Ref. 16) is not equivalent to ISO 1496/1 (Ref. 3). The CSC is primarily concerned with ensuring that

containers are safe for transport, are adequately maintained and are suitable for international shipment by all modes of surface transport whereas ISO 1496/1 addresses issues relating to the design and testing of containers. The testing specified in CSC is not equivalent to that specified in ISO 1496/1.

- Packages should be designed and tested to ISO 1496/1 (Ref. 3) and approved to CSC, which is the normal approval route within Great Britain. Although approval to CSC is not an IAEA regulatory requirement for approving radioactive material transport packages it is a statutory requirement for freight containers. Within Great Britain, implementation of the CSC is by means of the Freight Containers (Safety Convention) Regulations (Ref 18) and responsibility for administering the requirements of the International Convention for Safe Containers rests with the Health and Safety Executive (HSE). It is the HSE that appoint approved inspection bodies to approve containers in Great Britain and further guidance on freight container approval arrangements in Great Britain can be found in the HSE's "Green Guide" (Ref. 22).
- Depending on the level of containment for the package it may be possible to waive the ISO weatherproofness test where the containment leakage test can be shown to be a more onerous test. However, agreement should be sought from the Approval Authority and ISO/CSC approved inspection body prior to commencement of testing.

All type approval testing and the associated leakage testing shall be detailed on a testing quality plan which shall be separate to but referenced from the manufacturing quality plan.

4.3. Leakage Testing

Leakage testing shall be carried out during manufacture to demonstrate the required level of leak tightness has been achieved (see Ref.13 for leakage test methods).

For a prototype container, the leakage test regime shall comprise of:

- Leakage tests on the container body and closure seals on completion of manufacture prior to the commencement of type approval testing.
- A leakage test on the closure seals immediately prior to commencement of each of the ISO racking (rigidity) tests i.e. immediately before each of the racking test loads are applied.
- A leakage test on the closure seals during each of the ISO racking (rigidity) tests i.e. with the racking test load fully applied.
- A leakage test on the closure seals on completion of the ISO racking (rigidity) tests i.e. once the test load has been removed.
- A leakage test on the closure seals during each of the ISO side and end wall tests i.e. with the test load fully applied. Note: for top opening packages, where there are no closures in the end or side walls, it may be possible to omit the leakage test subject to agreement with the Approving Authority prior to commencement of testing.
- Leakage tests on the container body and closure seals on completion of the type approval test programme prior to application of the paint finish.
- A leakage test on the closure seals following application of the paint finish.

Following satisfactory completion of the prototype tests, leakage testing for all subsequent production units shall comprise of:

- Leakage tests on the container body and closure seals on completion of manufacture prior to application of the paint finish.
- A leakage test on the closure seals following application of the paint finish.

4.4. Batch Testing

Once a manufacture has obtained type approval and commences production of an approved design type, batch testing shall be carried out to ensure that containers of the same design type series are manufactured to the approved design.

The batch test requirements specified by the HSE (Ref. 22) comprises of the 'top lift' test, in conjunction with measurement of deflections of the floor structure under test load and an overall dimensional check. However for freight containers manufactured outside of Great Britain, in accordance with the International Convention for Safe Containers (Ref. 16), the manufacturer shall agree batch test requirements with the relevant Administration.

Although the CSC regulation states, "…..the Administration shall examine or test as many units as it considers necessary, at any stage during production of the design type series concerned." the minimum sample frequency for batch testing is usually set at 1 unit in 50 or 1 unit per production run where the production run quantity is less than 50 units.

5. Approvals

5.1. CSC Approval

CSC approval is not a requirement for compliance with the IAEA regulations; however it is a requirement for compliance with the Freight Containers (Safety) Convention Regulations (Ref. 18).

On successful completion of prototype type testing the ISO/CSC approved inspection body will issue a type approval certificate for the freight container which confirms it meets the ISO 1496/1 and CSC requirements. The manufacturer will then affix the CSC Safety Approval Plate to the container. The Safety Approval Plate bears the approval reference and number allocated by the approving organisation, the identification number of the container, its maximum gross weight and the date of container manufacture. Note the approved inspection body is only validating the ISO and CSC requirements they are not concerned with the containment tests.

5.2. Regulatory Approval

The Regulations do not require Competent Authority approval for Industrial Packages provided the contents are non-fissile or fissile excepted [674] [675].. However, the Competent Authority is responsible for ensuring that all radioactive material transport packages comply with the requirements of the Regulations [311] and they may at any time carry out audits on the procedures of organisations producing such packages.

Industrial Packages are granted local approval through compliance certification. The regulatory requirements apply, though the actual method of approval may vary in different organisations: TCSC 1078 (Ref. 12) provides further guidance.

In preparation for licensing, the designer shall produce a Package Design Safety Report (commonly referred to as a PDSR) which forms the radioactive material transport package licensing application. Further guidance on the PDSR format, along with the supporting documentation requirements, for this type of package is given in TCSC 1078 (Ref 12).

6. Documentation

The amount and type of documentation for a package held by the package operator is dependent upon whether it is a bespoke package where the Intellectual Property Rights (IPR) for the package is owned by the package operator or a bought in (or leased) package where the IPR is not owned by the package operator. Responsibilities for ownership and retention of documentation should be specified and agreed in the contract. TCSC 1094 (Ref. 19) provides additional guidance on records management.

Bespoke package i.e. IPR owned

The documentation held by the package operator for a bespoke package where the IPR is owned by the package operator should include:

- Detail design drawings and calculations
- Manufacturing specification
- Manufacturing and testing quality plans
- Material certificates including welding consumables
- Manufacturing concessions and production permits
- Test records
- Test certificates
- Weld procedures
- Weld traceability records e.g. weld map
- Welder qualification certificates
- Inspection records
- Inspection certificates
- Package Design Safety Report
- Package design certificate of approval
- Operating and maintenance manual
- Facility specific operating instructions and operational quality plan
- Detailed maintenance instructions and maintenance quality plan
- Operational records
- Maintenance records
- Certificate of conformity

Bought in or leased package i.e. IPR not owned

As a minimum, the documentation held by the package operator for a ‘bought in’ or leased package where the IPR is not owned by the package operator should include:

- General arrangement drawings
- Test certificates
- Certificate of conformity
- Package design certificate of approval
- Operating and maintenance manual

- Facility specific operating instructions and operational quality plan
- Detailed maintenance instructions and maintenance quality plan
- Operational records
- Maintenance records

7. Operation

7.1. General

Transport operations shall be carried out under a BS EN ISO 9001 (Ref. 17) compliant quality management system which shall include the use of an operational quality plan covering all operational activities relating to:

- Package receipt
- Package unloading operations
- Package loading operations
- Package preparation for shipment

It is the responsibility of the Package Operator/Consignor to ensure that:

- All local and regulatory requirements governing radioactive materials and transport packages are complied with.
- Reference is made to the Certificate of Approval for the package to ensure compliance with approved contents and other shipment and operating requirements.

7.2. Pre-Shipment Checks

On package turnaround at consignor and consignee facilities, the following visual inspections and tests shall take place, where applicable, to ensure the package is serviceable. Reference shall be made to the Operational Quality Plan (OQP) and Operator Instructions/Checklists. Records of these activities shall be kept and where any defects or difficulties are reported the package shall be taken out of service until the defect has been rectified.

- Check CSC plate to ensure container is in date and will remain so for the duration of the shipment.
- Carry out a visual examination of the container, both internally and externally, for signs of damage or defect. Pass/fail criteria shall be in accordance with IICL-6 (Ref 19).
- Inspect all lifting, fastening and tie down features for signs of fatigue or excessive wear.
- Confirm the HEPA filter, where required, is correctly fitted, clean and serviceable.
- Ensure the required markings, identification labels/plates and warning labels are in place, legible and free from damage. TCSC 1073 (Ref. 15) gives further guidance on labelling and marking requirements.
- Check the closure seals and the sealing surfaces against which the seal seats. Ensuring that the seals and seal faces are clean and free from damage or debris;

the seals are correctly seated and any features that secure the seal to the package are in place.

- Check for debris inside package.
- Perform seal leak tests to ensure integrity of containment seals, where required (see note below).
- Check the closure operation for correct movement and seating.
- Check that the package certificate of approval for transport is valid and will remain so for the duration of the shipment.

Note: Where the package is fitted with test points to facilitate leak testing of the closure seals, and a practical test can be conducted in the field, a seal leak test may be carried out prior to shipment. However, as a minimum for this type of package, a visual inspection of the seals and sealing faces prior to shipment may suffice to give confidence that the seals still perform to the design standard. During the early operational life of a new package design however, it may be necessary to conduct leak tests more frequently to build confidence in the sealing system. Thereafter, once the necessary operational experience has been gained, it should be possible to reduce the frequency of testing accordingly.

7.3. Consignment Documentation

The Consigner shall complete the necessary consignment documentation as required by the Modal Regulations, the Certificate of Approval for the package, the Consignors Site Procedures and the Consignees conditions for acceptance ensuring that the correct serial number of the package to be shipped is quoted.

7.4. Handling

The methods employed in handling and securing this type of package shall conform to BS ISO 3874 (Ref. 21).

8. Maintenance

8.1. General

All maintenance activities shall be carried out under a BS EN ISO 9001 (Ref. 17) compliant quality management system which should include the use of a maintenance quality plan and checklists.

All maintenance activities on ISO freight containers are required to be performed in accordance with the requirements of the International Convention for Safe Containers [Ref. 16]. However routine maintenance activities, additional to those required under CSC, are required to demonstrate the continuing satisfactory performance of the containment and payload restraint systems.

The maintenance records shall be entered into the Lifetime Quality Record (LQR) for the package.

There are no maintenance requirements for single use packages, other than the pre-shipment checks as detailed in Section 7.2.

8.2. Routine Maintenance Requirements

The level and periodicity of the routine maintenance requirements will be dependent upon the frequency of use of the package but should, as a minimum, be carried out annually.

The routine maintenance activities shall be carried out by a suitably qualified and experienced person but not necessarily by a HSE approved container inspection authority except when carried out in conjunction with the CSC examination.

The routine maintenance requirements shall, as a minimum, include:

- A visual examination of the container structure, both internally and externally, for signs of damage or defect. Pass/fail criteria shall be in accordance with IICL-6 (Ref 19).
- A visual examination of all lifting, fastening and tie down features for signs of fatigue or excessive wear.
- A visual examination of the HEPA filter, where fitted, to ensure it is clean, serviceable and correctly fitted.
- A detailed visual examination of the closure seals and the sealing surfaces against which the seals seat. Ensuring that the seals and sealing surfaces are clean and free from damage or debris; the seals are correctly seated and any features that secure the seal to the package are in place.
- Conducting a satisfactory leakage test on all closure seals.
- A visual examination of all moving parts for signs of fatigue or excessive wear.
- Ensuring adequate levels of lubrication are present on all hinges and mechanisms.

Whole body pressure/leakage testing is normally carried out during manufacture, to test the materials and the manufacturing process. Such testing can be hazardous and is considered unnecessary to repeat through life since wholesale degradation of the package structure is unlikely. However, where the containment boundary of the package has been damaged and repairs carried out the package must be subjected to a whole body leak test or localised leak test, to prove the containment integrity of the package.

8.3. CSC Requirements

Examination Schemes

Within Great Britain, ISO freight containers are approved as freight containers under the provision of the CSC Periodic Examination Scheme (PES). Under this scheme all new containers are approved for a period of five years from the date of first registration. After this initial five-year period (or any period during which the container registration has lapsed) the containers must be examined and re-approved as being suitable for another period of service, which can be up to a maximum of 30 months. Thereafter, the freight container must be re-examined for additional periods of service up to 30 months as specified by a HSE approved Container Inspection Authority. However the convention (Ref. 16) notes that, where containers are subject to a high frequency of handling and shipment, it may be necessary to increase the frequency of inspection.

Alternatively, the containers can be operated under an Approved Continuous Examination Programme (ACEP) provided that it can be demonstrated to the satisfaction of the HSE that such a programme provides a standard of safety not inferior to the PES. Examinations carried out under an ACEP are performed in connection with major repair, refurbishment, or on-hire/off-hire interchange and in no case less than once every 30 months. Unlike the PES, the ACEP does not allow an interval of 5 years before the first examination of new containers but otherwise the examination procedures are the same. All containers operated under an ACEP shall have a decal fitted adjacent to the Safety Approval Plate displaying the legend “ACEP-GB” followed by the 3-digit number allocated by the HSE when approving the scheme.

Examination under PES/ACEP is carried out by a HSE approved Container Inspection Authority in accordance with IICL-6 (Ref. 20). If on completion of the examination the package is found to be in need of repair the Inspection Authority will discuss and agree the extent of repairs required with the package owner.

NOTE: The examinations carried out under either PES or ACEP are in addition to the routine operator inspections and turnaround maintenance activities and must be carried out by a HSE approved container Inspection Authority.

NOTE: Leakage testing to demonstrate radiological containment is not part of the examinations carried out under either PES or ACEP.

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