IAEA SAFETY STANDARDS

for protecting people and the environment

Step 7 Rev.1

Resolutions of comments received from Review Committees:

- **TRANSSC**
- **RASSC**
- **WASSC**
- **NUSSC**

(to be the DRAFT for MS review for Step 8)

Ageing Management and Maintenance of Packages for the Transport of Radioactive Material

DS546

DRAFT SAFETY GUIDE

New Safety Guide

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition [1] (hereinafter referred to as the ‘Transport Regulations’), introduced important requirements to take into account the ageing of transport packages including, as relevant, their radioactive contents. The design of such packages is required to be based on evidence that these requirements have been met (see para. 613A of the Transport Regulations). This includes packages used for shipment after storage (see para. 809(f) and 809(k) of the Transport Regulations).

1.2. Recommendations on the application of the requirements of the Transport Regulations, including those related to ageing management, are provided in IAEA Safety Standards Series No. SSG-26 (Rev. 1), Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition) [2]. Recommendations on the incorporation of ageing considerations and an ageing management programme into the package design safety report[1] are provided in IAEA Safety Standards Series No. SSG-66, Format and Content of the Package Design Safety Report for the Transport of Radioactive Material [3].

1.3. The Transport Regulations also include requirements for maintenance of transport packages. SSG-66 [3] recommends that evidence of maintenance is used when preparing the package design safety report. SSG-26 (Rev.1) [2] also addresses maintenance of transport packages with respect to lifting attachments and ageing management of transport packages.

OBJECTIVE

1.4. The objective of this Safety Guide is to provide recommendations on ageing[2] and maintenance[3] of transport packages in order to ensure compliance with the Transport Regulations.

1.5. The recommendations in this Safety Guide are aimed at: designers of packages; manufactures; owners and the maintenance organizations of the packagings; owners of the radioactive content of the package; users (consignors) of the package; organizations responsible for the storage where the packages are stored before shipping (shipment after storage); technical support organizations; and competent authorities with responsibilities for the safe transport of radioactive material.

[1] In the context of this Safety Guide, the phrase ‘package design safety report’ is intended to mean all documentary evidence of compliance of a transport package design with Transport Regulations.

[2] In the context of this Safety Guide, the phrase ‘ageing’ is intended to mean physical ageing of package components, including radioactive content of the package when appropriate.

[3] In the context of this Safety Guide, the phrase ‘maintenance’ is intended to mean the organized activity, both administrative and technical, of keeping package components in good operating condition, including both preventive and corrective (or repair) aspects.

SCOPE

1.6. This Safety Guide covers all packages containing radioactive material (i.e. Excepted, Type IP-1, Type IP-2, Type IP-3, Type A, Type B(U) or B(M), Type C packages, including packages containing fissile material or uranium hexafluoride), as defined in the Transport Regulations.

1.7. This Safety Guide also covers all activities during the service life[4] of transport packages, in which ageing management and maintenance are to be considered.

1.8. A graded approach is applied to the recommendations provided in this Safety Guide, commensurate with the type of package and its intended use (i.e. single transport, repeated use, shipment after storage).

STRUCTURE

1.9. This Safety Guide consists of nine sections and three appendices. Section 2 provides recommendations on applying a graded approach to ageing mechanisms. Section 3 provides recommendations on the relationship between package operating conditions and ageing mechanisms. Section 4 provides recommendations on ageing considerations in package design and management of ageing. Section 5 provides overall recommendations on maintenance activities and considerations in package design; and on inspection and testing in maintenance of transport packages. Section 6 provides recommendations on the maintenance programme. Recommendations on the role of the competent authority in relation to ageing management and maintenance of transport packages and related administrative matters are provided in Sections 7 and 8, respectively. Section 9 provides recommendations on the interfaces between transport and storage, and between countries of origin, storage, and use of a package.

1.10. Appendix I provides examples of approaches for consideration of ageing mechanisms in package design. Appendix II provides an example structure of an ageing management programme. Appendix III describes roles and responsibilities of the relevant interested parties[5] considered in ageing management and maintenance of transport packages.

2. THE APPLICATION OF A GRADED APPROACH TO THE CONSIDERATION OF AGEING MECHANISMS ON TRANSPORT PACKAGES

[4] In the context of this Safety Guide, the phrase ‘service life’ is intended to mean the period from initial operation to final withdrawal of the transport package from its service.

[5] In the context of this Safety Guide, the phrase ‘relevant interested parties’ is intended to mean the different entities that may be involved in the ageing management and maintenance operations of a package: the package designer, the manufacturer and the owner of the packaging, the owner of the radioactive content of the package, the user (consignor) of the package, the maintenance organization of the packaging and the operator of the storage facility for shipment after storage.

2.1. The effects of ageing mechanisms[6] on packaging components, radioactive contents and package safety functions depend on the environmental and operational conditions to which they are exposed. A graded approach should be applied to the consideration of the ageing mechanisms to packages commensurate to the package operational conditions throughout its service life as described in paras 613A.1–613A.6 of SSG-26 (Rev.1) [2]. Considerations for ageing management are divided into three types of use of packaging; packagings intended to be used for a single transport, repeated use, and shipment after storage (see paras 613A.2–613A.4 of SSG-26 (Rev.1) [2]), as described in paras 2.3–2.9 of this Safety Guide.

2.2. For packagings that will be loaded after prolonged storage since their manufacture, the effects of ageing mechanisms should be considered whether they are intended to be used for a single transport or for repeated use.

PACKAGINGS INTENDED TO BE USED FOR A SINGLE TRANSPORT

2.3. Paragraph 613A.2 of SSG-26 (Rev.1) [2] states:

> "For packagings used once for a single transport and not intended for shipment after storage, inspection prior to use may be sufficient. Such packages may include excepted packages, Type IP-1, Type IP-2, Type IP-3 and Type A packages (e.g. fibreboard boxes, drums)."

PACKAGINGS INTENDED FOR REPEATED USE

2.4. Paragraph 613A.3 of SSG-26 (Rev.1) [2] states:

> "For packagings intended for repeated use, the effects of ageing mechanisms on the package should be evaluated during the design phase in the demonstration of compliance with the Transport Regulations."

The effect of the ageing mechanisms on its radioactive contents should not normally need to be considered because the duration of a single transport is relatively short (i.e. equal to or less than one year). Based on an evaluation, measures should be defined as part of the inspection and maintenance programme on the packaging to monitor and control ageing effects[7] to ensure that the safety functions of the packaging do not deteriorate over its service life. The inspection and maintenance might be conducted when the packaging is empty (i.e. without radioactive contents) between shipments of the loaded package (see Section 5).

[6] In the context of this Safety Guide, the phrase 'ageing mechanism' is intended to mean a process that gradually changes the characteristics of a package component over time or with use (e. g. curing, wear, fatigue, creep, corrosion, erosion, microbiological fouling, embrittlement, chemical decomposition).

[7] In the context of this Safety Guide, the phrase 'ageing effects' is intended to mean effects on the ability of package components produced by ageing. In case the ability to function within its acceptance criteria is impaired, they may be called as ageing degradation.

2.5. Considerations of ageing mechanisms, with appropriate justifications, should be included in the package design safety report.

PACKAGINGS INTENDED TO BE USED FOR SHIPMENT AFTER STORAGE

2.6. Paragraph 106.2 of the SSG-26 (Rev.1) [2] states that "Shipment after storage…is a specific shipment operation that requires consideration of ageing of package components[8]". Shipment after storage includes cases in which packages loaded with their radioactive contents are transported to a facility and then stored for several years or decades until being transported from the facility. In some cases, packages are loaded and stored at the same facility for a long time, then shipped to an outside facility. There might also be cases in which packaging has been used for repeated transport and then is used for storage.

2.7. The consideration of ageing mechanisms should take into account the following issues, as appropriate:

(a) The transportability of a package intended for use after storage should be maintained during storage. The ageing management programme and the gap analysis programme[9] should ensure that the package complies with the requirements of the Transport Regulations at the time of shipment after storage.

(b) It should be recognized that the package configuration for transport and the configuration for storage may differ. For instance, dual purpose casks[10] may be stored without shock absorbers.

(c) The impact of ageing effects on the radioactive contents should be considered in the ageing management programme and the gap analysis programme. This should include a consideration of whether the characteristics of the radioactive contents might change during storage and affect the safety functions of the package.

(d) Inspection and maintenance during storage should be designed so that they can be conducted on the loaded packages. Where it is not possible to directly inspect and maintain the loaded package during storage (e.g., if the primary container of the package is enclosed within a shielded overpack or shielded vault during the storage period) alternative means could be used to assess aging effects. For example, an empty packaging of the same design could be placed in the same storage conditions and at the same starting time as the loaded package. The empty packaging could be periodically retrieved, disassembled, and inspected. The ageing effects due to the storage conditions (e.g.,

[8] In the context of this Safety Guide, the phrase 'package component' is intended to mean an individual part and material, that make up packaging and its radioactive contents, necessary to perform safety function or other functions needed to comply with regulatory requirements.

[9] As stated in para. 809.4 of SSG-26 (Rev. 1) [2], "A gap analysis is a periodic assessment of whether the package design complies with the current Transport Regulations. It should consider changes of the regulations, changes in technical knowledge and changes of the state of the package design during storage, and then identify any gaps. The gap analysis programme should describe the procedure for conducting such a gap analysis."

[10] In the context of this Safety Guide, the phrase 'dual purpose cask' is intended to mean the assembly of components (packaging) necessary to fulfil the safety function for transport and storage of radioactive material.

temperature variations and humidity) on the empty packaging would be representative of the ageing effects on the loaded package.

2.8. Consideration of ageing mechanisms, with appropriate justifications, should be included in the package design safety report. For the package design approval, this evidence and a gap analysis programme is required to be submitted to the competent authority (see paras 809(f) and (k) of the Transport Regulations).

3. PACKAGE OPERATING CONDITIONS AND RELEVANT AGEING MECHANISMS

3.1. For some types of packages, the ageing management approach applied to the consideration of ageing mechanisms for transport packages might be follow the fundamental principles used for nuclear power plant components. Recommendations on ageing management for nuclear power plants are provided in IAEA Safety Standards Series No. SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants [4] and further information in Refs [5, 6]. Information on the approach to ageing management in an individual Member State is given in Refs [7–10]. The interim storage of spent nuclear fuel and the use of dual purpose casks has strengthened the focus on the consideration of ageing mechanisms for storage packages (e.g. see Refs [11–14]).

SERVICE LIFE OF TRANSPORT PACKAGES

3.2. Ageing is a time-dependent phenomenon and therefore may depends on the service life of the package. Although it is usually difficult in practice to establish a priori a specific service life for a package design as it often might depend on some unpredictable factors, the designer should consider the ageing mechanisms that might occur in the course of an expected service life of the package.

3.3. The expected service life might be expressed in terms of the number of years of use or the number of shipments. To consider ageing mechanisms, both the in-service duration (i.e. with the packaging subjected to the loads caused by the radioactive contents and transport operations) and the out-of-service duration (subjected to the storage environment) should be considered.

3.4. Nevertheless, if it is not practicable to set a limit on the duration or on the number of shipments, the performance of the packaging should be ensured by an appropriate maintenance. If the transport period is short, then there should be no need to consider the effects of ageing mechanisms on the radioactive contents, provided this is adequately justified in the package design safety report.

3.5. Additionally, for the packagings intended to be used for shipment after storage, the service life should consider the storage period of the package and phases before and after storage, including operations such as loading, movement and transport. The radioactive contents may be stored for a period of time in the package, thus the effect of ageing mechanisms on the radioactive contents should be considered taking into account any changes that might affect the integrity of the contents, loads to which packaging components are subjected to, and the retrievability of the contents. The possible effects of heat generation due to radioactive decay and the possible effects of irradiation on package components should also be considered.

ENVIRONMENTAL AND OPERATIONAL CONDITIONS

3.6. The package designer should define restrictions of expected environmental and operational conditions to which the packaging might be subjected to. These may include the following:

(a) General external and internal conditions:

General conditions during loading, shipment, unloading and specific ambient conditions during storage of empty packaging (e.g. outdoor or indoor, uncovered or covered) should be considered, such as humidity, temperatures or chemical and biological factors.

The internal atmosphere of the package cavity (e.g. air or a filling gas, such as helium and nitrogen) should be defined to evaluate the ageing effects on the radioactive contents and internal components. Leaktightness criteria need to be specified. Dry storage needs special specifications for drying. For packagings intended to be used for shipment after storage, the expected ambient conditions during storage, which might be defined in or derived from the storage facility design specifications, should be considered. The storage configuration (i.e. vertical or horizontal on a concrete pad or floor, storage frame, outdoors, and in a building) should also be considered, if they affect the ambient conditions.

(b) Mechanical loadings:

For all transport packages, the mechanical loadings acting on the packaging components during routine conditions of transport (including those caused by acceleration, vibration, and resonance) should be considered. For lifting attachments, such as trunnions, the cumulative number of liftings may also be considered.

For packagings intended to be used for shipment after storage, the mechanical loadings, as defined by the package designer for the conditions of storage should also be considered.

(c) Thermal loadings:

For repeated use packagings, all thermal loadings that increase the temperature of package components should be considered. These include the decay heat of the radioactive contents and the solar insolation data specified in Table 12 of the Transport Regulations. The daily fluctuation of the insolation might have an effect on the ageing mechanisms.

For packagings intended to be used for shipment after storage, the thermal loadings, as defined by the package designer for the conditions of storage should be considered. These loadings are the decay heat of the radioactive contents and the insolation in the case of outdoor storage.

(d) Irradiation:

For repeated use packagings, the effects of cumulative irradiation (gamma and neutron) during their service life should be considered.

For packagings intended to be used for shipment after storage, the effects of cumulative irradiation (gamma and neutron) during the intended storage period should be considered. The decay in the radioactive contents during storage should also be considered.

(e) Internal pressure:

The increase in the internal pressure of the package should be considered, if applicable in accordance with the package design.

AGEING MECHANISMS RELEVANT TO TRANSPORT PACKAGES

3.7. The most common ageing mechanisms specific to transport packagings that should be considered, depending on the package design, are as follows [14]:

(a) Boron depletion,: degradation of the neutron-absorbing capacity of the neutron poison and shielding materials when exposed to neutron fluence.

(b) Corrosion: electrochemical reaction of a metal or a metal alloy in an environment, which results in material oxidation or loss. The following are typical forms of corrosion:

 (i) Crevice corrosion: localized corrosion in joints, connections, and other small, close-fitting regions that develop local aggressive environments.

 (ii) Galvanic corrosion: accelerated corrosion of a metal when is in electrical contact with a more noble metal or a non-metallic conductor in a corrosive electrolyte.

 (iii) General corrosion: uniform loss of material caused by corrosion, which proceeds at approximately the same rate over a metal surface.

 (iv) Microbiologically influenced corrosion: any form of corrosion influenced by the activity of microorganisms, such as bacteria, fungi and algae, and/or the products of their metabolism. For example, anaerobic bacteria can establish an electrochemical galvanic reaction or disrupt a passive protective film, acid-producing bacteria can produce corrosive metabolites. Wood corrosion bacteria might degrade the wood used as a shock absorber.

 (v) Pitting corrosion: a localized form of corrosion confined to a point or small area of a metal surface in the form of cavities (‘pits’).

(vi) Intracrystalline corrosion: selective attack to the structure of a metal in the grain boundaries or adjacent. Materials susceptible to intracrystalline corrosion could include, for example, stainless steel, copper–zinc alloys and some aluminium alloys.

(c) Stress corrosion cracking: metal cracking produced by the combined action of corrosion and tensile stress (applied or residual). Stress corrosion cracking is highly chemically specific, in that, certain alloys are likely to undergo this type of corrosion only when exposed to certain chemical environments.

(d) Stress relaxation: loss of preload in a heavily loaded bolt. Over time, the clamping force provided by a bolt might decrease.

(e) Wet corrosion and blistering: degradation mechanism for neutron poison plates with open porosity as a result of water entering the pores of the material during loading, which leads to internal corrosion. Blisters occur from the trapped hydrogen produced by the corrosion reactions. Wet corrosion and blistering can cause dimensional changes affecting the criticality considerations due to moderator displacement and might hinder the retrieval of fuel assemblies.

(f) Creep: for a metallic material, time-dependent continuous deformation process under constant stress. It is a thermally activated process and generally a concern at temperatures greater than 40% of the absolute melting temperature of the material.

(g) Fatigue c(also called ‘cyclic loading’ or ‘thermal/mechanical fatigue’): phenomena leading to fracture under repeated or fluctuating stresses with a maximum value less than the tensile strength of the material.

(h) Radiation damage: loss of ductility (embrittlement), fracture toughness, and resistance of metal and polymer cracking that might occur under exposure to radiation.

(i) Radiolysis: in broad meaning, material change caused by the breaking of chemical bonds by irradiation. For example, when water exists in the package cavity, hydrogen is generated by radiolysis, which causes an internal pressure buildup in the package. Polymers might change in composition, due to decomposing of crosslinks by irradiation.

(j) Thermal ageing: continued exposure to elevated temperatures during operation can sometimes result in undesirable properties.

(k) Wear: surface material removal caused by relative motion between two surfaces or under the influence of hard, abrasive particles. Wear occurs in parts that experience intermittent relative motion or frequent manipulation.

3.8. Examples of ageing mechanisms specific to nuclear fuel, especially for spent nuclear fuel, include the following [14]:

(a) Delayed hydride cracking: crack propagation in zirconium-based cladding materials resulting from hydrogen diffusion to a crack tip and embrittlement of the near-tip region due to hydride precipitation. The operability of the delayed hydride cracking mechanism in fuel cladding depends on the stress imposed on the cladding.

(b) Hydride reorientation and hydride-induced embrittlement: precipitation of radial hydrides resulting in the embrittlement of zirconium-based cladding materials. The hydride reorientation from the circumferential-axial to the radial-axial direction is caused by heating and cooling of the cladding under sufficient cladding hoop tensile stresses and might affect the performance of the cladding under pinch load stress.

(c) Mechanical overload: overload of fuel cladding caused by fuel pellet swelling. The fuel pellet swelling is the result of the decay gas production in the pellet. Pellet swelling can increase stresses on the cladding.

IDENTIFICATION OF THE SAFETY RELEVANT COMPONENTS IN TRANSPORT PACKAGES

3.9. In accordance with para 104 of the Transport Regulations, the following four safety functions are required to be satisfied during the transport of radioactive material:

(a) Containment of the radioactive contents;

(b) Control of external dose rate;

(c) Prevention of criticality;

(d) Prevention of damage caused by heat.

3.10. A systematic scope setting process should be used for identifying components subject to the ageing consideration; all package components, including radioactive contents, where relevant, should be listed. The following components should be included by the package designer in the scope of ageing considerations in the package design safety report (See Fig. 1) [4].

(a) Components important to safety and necessary to fulfil one or more safety functions of the package. Examples are containment system components such as shell, bottom plate, lid(s), lid bolts, gasket, orifices and valves, gamma and neutron shielding, fuel baskets; and cooling fins and thermal paths.

(b) Other components whose failure might prevent the components important to safety from fulfilling their intended functions. Examples are shock absorbers, trunnions and lifting lugs.

(c) Other components credited in the safety analyses as performing the function of coping with certain types of event, consistent with the Transport Regulations and national requirements. Examples are barriers to prevent access or persons touching the package (mesh plates), seals to detect opening of packages and name plates.

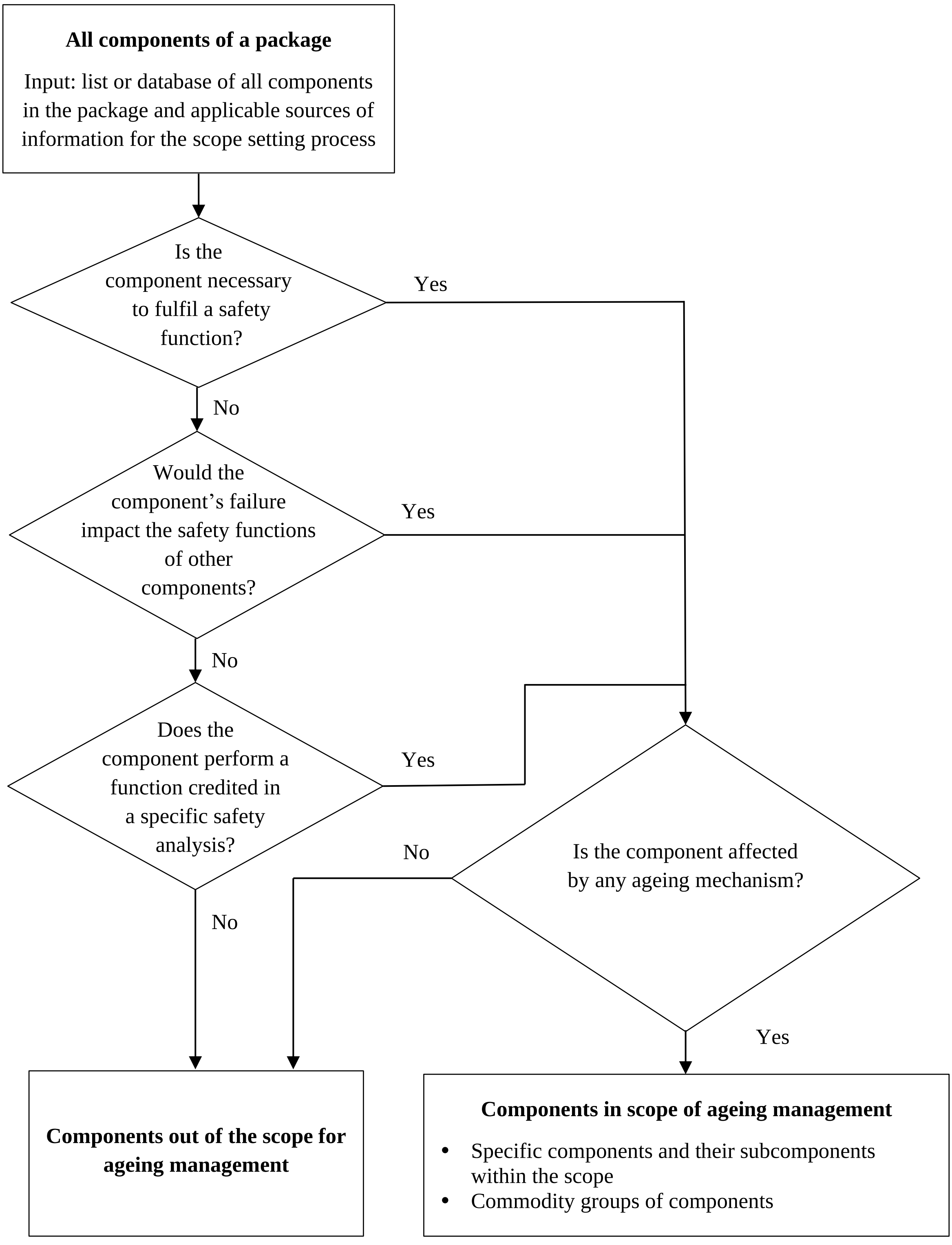

FIG. 1. Scope setting process for ageing management

MATERIALS OF SAFETY RELEVANT COMPONENTS IN TRANSPORT PACKAGES

3.11. The materials of safety relevant components in a transport package should be listed to complete the scope setting process for ageing management described in para. 3.10. Examples of typical materials used for components of packaging include the following [14]:

(a) Aluminium or aluminium alloys: used as a cladding of metallic gaskets for closure seals, or as a structural component or heat conductor (e.g. baskets for locating spent fuel assemblies or as a cladding material).
(b) Borated aluminium: used as a neutron absorber of a structural or non-structural member of a basket for nuclear fuel.
(c) Borated stainless steel: used as a neutron absorber of a structural member of a basket for nuclear fuel.
(d) Concrete: used as structural member and shielding.
(e) Copper or copper alloys: used as a rupture disk or a heat conductor.
(f) Depleted uranium: used as a shielding material.
(g) Ductile cast iron: used as a structural member or as shielding material.
(h) Inorganic material: ceramic fibres used for thermal insulation; inorganic compounds used for neutron shielding.
(i) Lead: used as a shielding material.
(j) Nickel or nickel alloys: used as a closure lid, plate bolt or trunnion bolt, or as an inner cladding and spring, mainly for the metallic gasket for the lid seal, or as a cladding for corrosion protection purposes.
(k) Other neutron absorber and neutron shielding material: high-hydrogen-containing material such as water, polymer or polymer compounds (resin, polyethylene), used as shielding; boron or B_4C may be used to absorb neutrons and suppress secondary gamma ray, and also for subcriticality purpose.
(l) Paint: used as a surface coating material (e.g. protection against corrosion, thermal emissivity).
(m) Tungsten: used as a shielding material.
(n) Silicone resin: used as a filling or sealing material for gaps, notches or holes to prevent the aggregation or ingress of moisture.
(o) Silver: used as a cladding of the metallic gasket for lid seals.
(p) Stainless steel (austenitic, ferritic, duplex or martensitic): used as a structural member, shielding material, corrosion-resistant lid gasket seating surface and nuclear fuel cladding tube (older designs).
(q) Steel (i.e. carbon, alloy, high-strength and low-alloy steels): used as structural member or as shielding material.

(r) Synthetic rubber: used as an elastomer O-ring for the closure seal.

(s) Woods or foamed polymer (e.g. polyurethane): used as a shock absorbing material.

(t) Zirconium-based alloys: used as a cladding tube of nuclear fuel.

4. AGEING CONSIDERATIONS IN PACKAGE DESIGN AND MANAGEMENT OF AGEING

4.1. The package design should be documented in a package design safety report by the package designer to provide evidence of its compliance with the applicable Transport Regulations. For package designs that require approval by a competent authority, the package design safety report should be the basis for the application to the competent authority.

4.2. SSG-66 [3] provides a package design safety report format, including a section for ageing considerations. The ageing effects on packaging and radioactive contents should be considered in the scope setting process for ageing management described in para. 3.10. The items that should be addressed by the package designer include the following:

(a) Identification of intended conditions during service life that might influence ageing:

The conditions include environmental and loading conditions during transport and storage (loaded and empty packages).

(b) Identification of potential ageing mechanisms that are relevant to the package design, taking into account the environmental and loading conditions during the service life of the package:

The components to be considered and their materials should be listed (see paras 3.10-3.11). The potential ageing mechanisms, based on the conditions during the service life, should then be listed. Then the components that may be subject to ageing effects together with the ageing mechanisms involved should be identified and tabulated. Appendix I contains an example of this process.

(c) Analysis of the influence of ageing on the design assumptions for demonstration of compliance with the Transport Regulations and measures to be taken:

The materials and ageing mechanisms identified in (b) should be evaluated. If such effects have the potential to adversely affect the safety functions of the package (i.e. as assumed in the package design), preventive measures should be incorporated in the design and/or in operation. Appendix I includes typical methods to evaluate ageing effects and measures considered in the design of packages to prevent adverse effects due to ageing.

(d) Compilation of operational measures:

The operational measures for detecting ageing effects and preventing adverse effects on the safety of packages (e.g. maintenance, inspections, monitoring and restrictions on conditions of use) should be stated (see Section 5 and 6).

APPROACHES TO AGEING MANAGEMENT FOR TRANSPORT PACKAGES

4.3. A general approach to considering ageing mechanisms for transport packages is shown in Table 1.

4.4. The considerations of ageing mechanisms and their effects on the package should be included in the package design safety report (i.e. in the section on 'AGEING CONSIDERATIONS') [3]. For each combination of packaging component material and ageing mechanism (see para. 4.2(c)), the package designer should evaluate the effects of ageing on the functions of components and the safety functions of the package, and should define restrictions of environmental conditions and safety criteria of components including relevant inspections to control them. . The evaluation of ageing should be based on the package design and its operational conditions and service life.

4.5. Some typical items of concern for ageing effects are listed in Appendix I.

AGEING MANAGEMENT PROGRAMMES FOR TRANSPORT PACKAGES

4.6. The ageing mechanisms and effects should be addressed using an ageing management programme. Recommendations relevant to an ageing management programme are provided in SSG-48 [4], and further information is available in Refs [11, 15]. The typical content of an ageing management programme is presented in Appendix II.

TABLE 1: AGEING MANAGEMENT CONSIDERATIONS FOR TRANSPORT PACKAGES

	Packages intended to be used for a single transport	Packages intended for repeated use	Packages intended for shipment after storage
Management system	Management system of the responsible organization*, in accordance with para. 306 of the Transport Regulations	Management system of the responsible organization*, in accordance with para. 306 of the Transport Regulations	Management system of the responsible organization*, in accordance with para. 306 of the Transport Regulations or organization responsible for the storage
Package design (Package design safety report)	Relevant ageing mechanisms in accordance with para. 613A of the Transport Regulations should be considered.	Relevant ageing mechanisms in accordance with para. 613A of the Transport Regulations should be considered for repeated use.	Relevant ageing mechanisms in accordance with para. 613A of the Transport Regulations should be considered for transport and storage.
	Relevant ageing effects should be considered in the design	Relevant ageing effects should be considered in the design	Relevant ageing effects should be considered in the design
	Pre-shipment inspection	Maintenance programme with periodic and pre-shipment maintenance and inspections	Maintenance programme with periodic and pre-shipment maintenance and inspections

			Ageing management programme to control and confirm that ageing effects are within an acceptable range as defined by the package design (see para. 809(f) of the Transport Regulations)
			Gap analysis programme for periodic evaluations of changes in regulations, in technical knowledge and the state of the package design during storage (see para. 809(k) of the Transport Regulations)
	Manufacturing confirmation for packaging conformity with the design, in accordance with para. 501 of the Transport Regulations	Manufacturing confirmation for packaging conformity with the design, in accordance with para. 501 of the Transport Regulations	Manufacturing confirmation for packaging conformity with the design, in accordance with para.501 of the Transport Regulations
	Shipment confirmation for package content and design, in accordance with paras 502 and 503 of the Transport Regulations	Shipment confirmation for package content and design, in accordance with paras 502 and 503 of the Transport Regulations	Shipment confirmation for package content and design, in accordance with paras 502 and 503 of the Transport Regulations
Package Operation	Pre-shipment inspection	Maintenance in accordance with a maintenance programme with periodic and pre-shipment inspections	Periodic maintenance during storage, in accordance with a maintenance programme
			Periodic monitoring of ageing effects in accordance with the ageing management programme
			Periodic monitoring of gaps in terms of compliance with new regulations and technologies, in accordance with a gap analysis programme

* The responsible organization is the entity responsible for design, manufacturing or operation of a package.

4.7. The ageing management programme for dual purpose casks containing spent nuclear fuel should be defined by following the approach in Appendix II or as described in Ref. [11]. An ageing management programme might also be defined for a package containing radioactive material other than spent nuclear fuel based on the information included Refs [11, 15] and in Appendix I and Appendix II. Other components that are not used during storage but are to be used for the shipment after storage (e.g. shock absorbers) should also be included in the ageing management programme.

4.8. The effectiveness of the ageing management programme should be periodically evaluated to take into account new knowledge and feedback from the programme; performance indicators should be updated and adjusted as appropriate. Relevant knowledge includes information on the operation of the component, surveillance and maintenance histories, information from the results of research and development, and operating experience.

Packagings intended to be used for a single transport

4.9. A wide range of packagings are designed to be used for a single transport. For packagings stored for a prolonged period of time (typically more than a year) before transport, any deformation, rust, corrosion, or other defect in the packaging should be detected by pre-shipment inspections. In such case, the packaging should be repaired or replaced.

Packagings intended for repeated use

4.10. A wide range of packages are designed for repeated use. The most common ageing considerations include the following:

(a) Package designs not requiring competent authority approval (excepted packages, industrial packages, Type A packages):

  (i) The activity of radioactive contents is relatively low; thus, the cumulative irradiation of package components and the decay heat from the radioactive contents are not significant, even after repeated use. Provided it is adequately justified in the package design safety report, no ageing effects due to irradiation or thermal loadings need to be considered.

  (ii) Any deformation, rust, corrosion, or other defects in the packaging should be detected by the maintenance programme, including pre-shipment inspections (see Section 5). Where such effects are detected, the packaging should be repaired or replaced.

  (iii) For an empty packaging that has previously contained radioactive material, ageing effects should have been evaluated in the assessment of the package when it was loaded with radioactive material.

  (iv) Cyclic mechanical loadings during handling and transport can contribute significantly to the development of ageing effects. These effects should be considered.

(b) Package designs that require competent authority approval (Type B(U), Type B(M) and Type C packages, and packages containing uranium hexafluoride (UF_6) or fissile material):

The considerations of ageing effects should take into account the activity of the radioactive contents permitted by the approval. Irradiation and decay heat can potentially cause ageing effects, and the usage of the containers (service life and number of shipments) is also a factor. The parameters to be included in the package design safety report should be justified and evaluated based on the specific package design.

  (i) Ageing management issues that can be taken into account include the following:

  — Embrittlement of stainless steel, carbon steel or low-alloy steel should only be considered for very high neutron irradiation levels [16]. Normally, the embrittlement of these materials need not be considered.

- Changes in the mechanical properties of aluminium and copper alloys should only be considered for very high neutron irradiation levels [17, 18]. Normally, these changes need not be considered.

- The ageing effects on lead used as shielding need not be considered. because no clear change in the properties of lead due to irradiation has been reported.

- The radiation resistance of resins (epoxy, silicone) should only be considered for very high neutron and gamma irradiation levels [19].

- In structural design and construction codes (e.g. Ref. [20]), the mechanical integrity of carbon steel and low alloy steel is up to 350°C, and up to 425°C for stainless steel. The temperature of these material used for a shell, a bottom plate, a lid, lid bolts, and trunnions during transport is less than 170°C; thus, creep in these components need not be considered. The temperature of the stainless steel basket for spent nuclear fuel is less than 180°C for a wet type package and less than 390°C for a dry type package; thus, creep and dimensional change in the basket need not be considered.

- Irradiation and thermal degradation of elastomer O-rings (e.g. for lid seals) need to be considered.

- Corrosion of the external surfaces of packaging made of carbon steel or low alloy steel should be considered. Sea salt particles and road chemicals during transport or storage environment might cause the initiation of pitting, crevice corrosion, and/or stress corrosion cracking on stainless steel surfaces. In case of internal storage, the monitoring of storage conditions, i. e. humidity and temperatures, to exclude any condensation on the package surfaces (Dew point) can be used to exclude all ageing mechanisms that require an electrolyte to take place.

- The fatigue of trunnions should be considered and the need to replace the trunnions should be determined when the number of lifting operations exceeds a calculated limit times to avoid a fatigue failure.

- Corrosion by bacteria and/or humidity on the wood used as a shock absorbing material should be considered. The concern is that wood corrosion will lead to dry rot or wet rot and result in a loss of strength and/or degradation of mechanical properties. Normally, this need not be considered, providing the wood is sealed tightly in a metallic casing and its surface is confirmed to be leaktight during maintenance and/or periodic inspection. The temperature and irradiation of the wood is low enough such that ageing effects (e.g. a change of mechanical property or decomposition of adhesive to form a plywood) need not be considered.

— No ageing effects on the radioactive contents need to be considered because the duration of a single transport operation is short (equal or less than one year).

(ii) Additional considerations on packages containing fissile material:

In the package design safety report, the ageing effects on any components that are intended to maintain subcriticality should also be considered. Examples of criticality related ageing considerations are as follows:

— For transport packages containing fresh (unirradiated) fuel, the effects of irradiation and temperature on the ageing of the packages are almost negligible.

— For transport packages containing spent fuel, the effects of high temperature should be considered because possible dimensional changes in the fuel basket might affect criticality safety. The depletion of ^{10}B used as the neutron absorber in the basket should be considered in terms of the effects on criticality safety.

— For transport packages containing spent fuel, the evaluation of thermal ageing for components made of precipitation hardened stainless steels and aluminium alloys should be considered if the components are located inside the package containment in close proximity to spent fuel.

(iii) Additional considerations on packages containing uranium hexafluoride:

Packagings for the transport of uranium hexafluoride are designed, manufactured, inspected, tested and maintained in accordance with international and national standards (i.e. Refs [21, 22]). The maintenance programmes specified in these standards have been established with considerations of the ageing mechanisms; thus, no further consideration of the potential ageing mechanisms is needed when these packages are maintained and inspected in accordance with such standards (see para. 613A.6 of SSG-26 (Rev.1) [2]).

Packagings intended to be used for shipment after storage

4.11. The considerations of ageing effects for packages intended to be used for shipment after storage are different to those for packagings intended for repeated use. The major differences are as follows:

(a) The condition of the radioactive contents during storage should be assessed, with due consideration of ageing effects, and this should be reflected in the package design safety report. The decay of the radioactive contents during storage should also be taken into account.

(b) Packages should maintain their safety functions and withstand the conditions of storage as well as transport (i.e. for shipment after storage).

(c) Transportability after storage should be ensured during the period of storage in order to ensure compliance with the requirement of para. 503(e) of the Transport Regulations.

4.12. General ageing management considerations in relation to the storage of spent fuel are given below (the specific information to be included in the package design safety report should be determined by evaluations of the specific package design):

(a) The containment function of the package during storage needs to be maintained. The metal gasket should be demonstrated (through testing and analysis) to be able to maintain its leak rate within the design limits over an storage period. The deterioration of the leaktightness during storage should be monitored, for example by inter-lid pressure monitoring for double-lid systems. Corrective actions should be taken in the case of leakage.

(b) For fuel baskets, the ageing effects of an elevated temperature environment for long term storage should be considered. For example, age-hardening aluminium alloy with a higher mechanical strength is used as the basket material; however, this alloy can eventually lose its enhanced strength in an elevated temperature environment.

(c) The ageing effect associated with changes in the behaviour of the radioactive contents, especially for spent fuel, should be considered (i.e. creep, hydride reorientation, embrittlement, oxidation, reconfiguration of fissile material).

5. MAINTENANCE OF TRANSPORT PACKAGES

5.1. Maintenance denotes planned inspections, tests and repairs to packaging (preventive and corrective maintenance). The purpose of repairs is to restore the condition as per the package design specifications by replacing and repairing components. A repair should be planned or take place as part of preventive maintenance or in response to unexpected events during operation. The scope of maintenance operations includes actions to detect and correct ageing effects and other actions necessary to prevent or repair damages occurring from the use of the packaging.

5.2. Maintenance of packaging should be performed before and/or after each shipment or at planned intervals. It should be indicated on the packagings when maintenance was previously undertaken or (preferably) when the next maintenance is due. The aim of this, in conjunction with appropriate maintenance records, should be to demonstrate that the packaging continues to comply with the Transport Regulations.

5.3. Consignors should plan transport operations in order to ensure that each packaging will be available for maintenance on schedule.

5.4. Typically, planned (periodic) maintenance might include the following:

(a) Routine maintenance (e.g. before loading of radioactive contents, and before and after each shipment);
(b) Short term (e.g. annually);
(c) Medium term (e.g. every 3–5 years);
(d) Long term (e.g. every 10 years);
(e) Maintenance after a specified number of shipments.

5.5. Planned maintenance is performed on a periodic basis that should be established by the designer in the package design safety report [3] and/or specified in the certificate of approval. This maintenance usually consists of a series of inspections and tests to demonstrate that the packaging retains the capability specified in the package design safety report for safely transporting the radioactive contents. Planned maintenance often includes the systematic replacement of some components (e.g. gaskets, seals, screws).

5.6. Unplanned maintenance of packaging should occur when a non-compliance is found during an inspection before or during use or when handling or transport cause the safety performance of the packaging to be impaired. This maintenance could include the replacement of broken thread inserts (such as helicoils); replacement of damaged couplings and valve fittings; or replacement of a damaged, removable part (such as a port cover or bolt).

5.7. A non-compliant package cannot be transported to another location if it is not in compliance with the Transport Regulations, except under special arrangement according to para. 238 of these Regulations [1]. In addition, depending on the degree of non-compliance, it might not be advisable to even move the package at all until it has been repaired.

5.8. The owner or user[11] of the package should implement or arrange for the maintenance of packaging. The designer should provide maintenance instructions to the owner or user.

[11] See Appendix III. In the context of this Safety Guide, the phrase 'owner or user' is intended to mean the organization or person responsible for ensuring that transport packagings are maintained throughout their service life. Depending on the specific circumstances, this may be the owner of the packaging or the user (consignor). Where packages are in extended storage (dual purpose casks) this may also include the operating organization responsible for the storage facility.

MAINTENANCE CONSIDERATIONS IN TRANSPORT PACKAGE DESIGN

5.9. The package designer should address the necessary maintenance arrangements within the package design safety report and provide the maintenance instructions to the owner and user of the package.

5.10. Maintenance needs of package components should be identified during design process, such as specifying the inspections, tests and replacement of components to be performed and the frequency and schedule for these activities.

5.11. When identifying maintenance needs, regulatory requirements, codes and standards, the conclusions of the package analysis, the properties or performance of the package materials and components, usage of the package components, fabrication techniques, and good practices should all be considered. When a purchased component is used in the package design it is often the vendor who specifies both the frequency and type of maintenance and testing. The recommendations of vendors should also be taken into account by the package designer.

5.12. The package design should facilitate access to components to perform maintenance operations.

MAINTENANCE ACTIVITIES ON TRANSPORT PACKAGES

5.13. Maintenance activities should be defined in operating and maintenance instructions, and also set out in the package design safety report [3], which should be made available to all relevant parties. These instructions should include all activities relevant to operation, inspection and repair of the packaging.

5.14. The person or organization performing the maintenance should be qualified and all maintenance activities should be performed in accordance with an appropriate management system (see paras. 6.13–6.16). The latest maintenance instructions approved in accordance with the management system should be made available to all relevant persons.

5.15. During the service life of the packaging, the owner and user should maintain sufficient records on the maintenance to demonstrate that the requirements of the package design safety report the Transport Regulations have been met. Documentation of the maintenance should be retained for the service life of the packaging. For multiple packagings of the same design, records should indicate the serial number of each individual packaging.

5.16. Corrective maintenance on packaging could lead to modifications of safety relevant components. These modifications could affect the safety analyses of the package design and/or its operating instructions. A package with such modifications might not be covered by the original package design safety report; therefore, potential design modifications should be analysed by the package designer to verify that the design will continue to comply with the Transport Regulations. If the result of the verification is that the modifications are not covered by the original package design safety report, an application for revision of the approval of the package design should be considered.

5.17. Where possible, maintenance should be performed using original spare parts and materials. If original components are not available, the use of other components should be analysed as a potential modification of the package design.

5.18. The process of analysing potential design modifications following corrective maintenance should be adequately documented [23]. The owner and user of the packaging should keep records of the modifications made, including the analyses performed. This documentation should be controlled and maintained in accordance with the management system and be made available to the competent authority on request.

5.19. The packaging may be inspected before and/or after each shipment, as appropriate to the design. In this case, the inspection results should be recorded and may be used as reference for periodic maintenance.

5.20. The components to be inspected may include the packaging exterior surface, the cavity, basket, O-rings and gaskets, seals, nuts and bolts, fasteners and their locking devices, padlocks or other securing devices, trunnions, lifting lugs, shock absorbers, valves, welding seams, coating, paintwork, and permanent markings [23].

INSPECTION AND TESTING IN MAINTENANCE OF TRANSPORT PACKAGES

5.21. The inspection and testing activities in the maintenance programme should be defined taking into account the classification of component of the packaging in accordance with their safety relevance (see para 3.10).

5.22. Inspection and periodic testing should be conducted in accordance with the maintenance instructions in the package design safety report provided by the package designer.

5.23. Visual inspection is a common and convenient method, which should generally be the first step in an inspection of packaging. Measurements, as appropriate, should then be used to verify that the exterior, dimensions and tolerances of the packaging comply with the design. Typically, visual inspection and measurements include checking the following:

(a) The condition of the exterior of the package;
(b) The legibility of permanent marking;
(c) The condition of liners, other internal parts, O-rings and gaskets for damage;
(d) Sealing surfaces for damage, corrosion and residual material (e.g. burrs);
(e) Wooden parts for drying, shrinkage, crushing when possible, or cracks and damages on the casing of shock absorbers;
(f) The condition and operation of closures, valves, ventilation patches and devices;

(g) The condition and operation of padlocks, lifting attachments and tie-downs;

(h) The condition of nuts and bolts, fasteners;

(i) The condition and operation of other parts or components, as necessary.

5.24. Examinations of welds (e.g. on seams of lifting lugs) may be conducted by non-destructive testing according to the information given by the designer in the maintenance instructions.

5.25. Components important to criticality safety, such as neutron absorption materials, should be inspected for deformation or displacement, if the geometry of those components is relied on for criticality safety.

5.26. Trunnions and lifting lugs should be visually inspected prior to each shipment for permanent deformation, galling, or cracking. Inspection results should be recorded and evaluated against established acceptance criteria. Trunnions should also be subjected to periodic tests. Critical areas, including basic bearing welded joints, should be subject to inspection for defects. When a loading test is performed, these inspections should be carried out after loading during a certain time and all components should be checked for residual deformation. The inspection methods may be dimensional verification, visual inspection, and non-destructive testing of critical areas.

5.27. For some package designs, normally intended for repeated use and requiring competent authority approval, the cask body should be subject to periodic pressure test. The test media may be gas or liquid. The pressure should be slowly increased and maintained at a fixed value for specific time in accordance with the design requirements.

5.28. For some package designs, a leaktightness tests should be conducted periodically and/or after seal parts replacement, prior to loading and after loading of the content. Gas leakage is monitored by several methods, helium leakage test can give more high sensitivity. Additional information is available in Ref. [24].

5.29. For some package designs, a thermal performance tests should be conducted, if applicable, during periodic maintenance used to verify the heat transfer capability over the service life of the packaging. Thermal performance can be evaluated by using the temperature measurement data obtained during transport. If possible, it may be conducted by using simulated heating sources, such as electrical heating devices, a system commonly used in thermal tests prior to the first shipment. Test should be performed in a homogeneous and stable thermal environment, allowing enough time to establish a constant temperature.

5.30. Shielding performance tests should include tests for neutron and gamma radiation shielding, as applicable. Shielding performance can be evaluated by using the dose rate measurement data obtained during transport or storage, or the test may be conducted during periodic maintenance.

5.31. Periodic tests and replacement schedules for components and packaging materials (e.g. screws, gaskets, valves, rupture disks) should be conducted, if indicated in the package design safety report or required by the competent authority.

6. MAINTENANCE PROGRAMME FOR TRANSPORT PACKAGES

6.1. The package design safety report [3] should include a description of the maintenance programme for transport packages as part of the maintenance instructions provided by the package designer.. The maintenance programme should address the following elements:

(a) The components of the package that are subject to a maintenance programme;

(b) Type and description of maintenance operations including inspection methods and tools and also reasoned argument for spot checks;

(c) The frequency of maintenance operations;

(d) The qualifications for personnel who will perform maintenance operations and quality control checks.

6.2. The maintenance programme should also include the following activities, as applicable:

(a) Maintenance requirements before and after each shipment;

(b) Maintenance activities that are needed at periodic intervals throughout the service life of the packaging;

(c) Maintenance requirements during periods of non-use.

6.3. The maintenance programme should include a scope with basic information on the type, model, and other general information of the packaging. The identification of its safety relevant components to be maintained should also be included in this section of the maintenance programme.

6.4. The maintenance programme should include a scheme that systematically address the content of para 6.1 (b), (c) and (d) for each component considered in the scope, including a description of planned inspections and the organisational procedures for implementing unplanned inspections, and instructions for the maintenance of the packaging.

6.5. The maintenance programme should establish maintenance records and the process for their making, archiving and retrieving. The aims of these maintenance records should be as follows:

(a) To record that maintenance has been performed in accordance with the package design safety report and certificate of approval, as applicable;

(b) To record the completion of inspection or test, and their result (including any corrective actions taken). The aim is to provide an audit trail regarding satisfactory performance of the past maintenance.

6.6. Records should be made in a format defined in the relevant procedure in accordance with the management system and should include all the tests and inspections defined in the maintenance programme for the package.

6.7. The maintenance records should contain the following information, as appropriate (see Ref. [23]):

(a) Reference to the procedure that specifies the maintenance requirements.

(b) The packaging identification such as model/design and serial number or identification reference.

(c) Components of the packaging subjected to inspection or maintenance.

(d) The inspections and tests performed.

(e) Compliance with the acceptance criteria. In some cases, this may be a simple pass/fail indication for the verification of each component of packaging. In other cases, practical acceptance criteria should be established. The acceptance criteria should be as defined in the relevant procedure.

(f) The name and signature of the qualified person who performed the maintenance (if necessary, at each step of the maintenance procedure).

(g) The name and signature of a qualified person responsible for quality control in steps involving instrumentation (such as pressure gauges and leak detectors).

(h) The validity period, i.e. the date when the next inspection or test is due.

(i) The serial numbers and calibration dates for the tools, equipment, and instrumentation used.

(j) Remarks and other information that needs to be recorded.

6.8. The maintenance procedure should be supported by the training and qualification records of the persons performing the work, and records of calibration, procurement and, if applicable, shelf life (for replacement parts). These records need also to be available for audit.

6.9. Additionally to the maintenance records, it is recommended also to provide an individual record (in the form of an electronic log or logbook) compiled for each packaging, in the case of complex designs (e. g. Type B(U), Type B(M) and Type C designs, packages containing fissile material), or for each package design in use for other cases, which will provide the following [23]:

(a) Information on possible findings encountered in the execution of maintenance activities that could necessitate modifications of the maintenance programme, e.g. by increasing or decreasing the frequency of the inspections or by setting stricter or lower test criteria.

(b) The operating experience from the use of the packagings (i.e. that might result in proposals for design improvements). This operating experience should be shared between the owner or user of the packaging and the designer.

6.10. The individual packaging records should contain the following information, as appropriate:

(a) Package design reference and unique serial number;

(b) A list of applicable references to the operating quality plans;

(c) Certificate number(s);

(d) Records of inspections and tests performed before first use;

(e) Maintenance records;

(f) Quality control records (e.g. modification certificates, repair certificates);

(g) List of non-compliances and corrective actions taken;

(h) Records of shipments.

6.11. When maintenance operations are to be performed at a point remote from the location where the detailed records are stored, the owner or user of the packaging should make available necessary records for the maintenance operation. The owner or user of the packaging should ensure that the maintenance records are available to the competent authority, on request (see also Appendix III).

6.12. The maintenance programme accordingly with the management system may establish procedures for the management of tools, equipment and spare parts used for maintenance, and appropriate records to be kept.

MANAGEMENT SYSTEM FOR THE MAINTENANCE PROGRAMME FOR TRANSPORT PACKAGES

6.13. The documentation of the maintenance and repair of packagings should be prepared, reviewed, and issued in accordance with the management system.

6.14. If the maintenance programme changed, including maintenance operations, instructions and/or technical parameters, the programme documentation should be revised and approved accordingly and re-issued to owners or users of the packaging.

6.15. Maintenance documents should be retained over a period of time specified by the management system, taking into account the type of packaging and its usage.

6.16. Further recommendations are provided in IAEA Safety Standards Series No. TS-G-1.4, The Management System for the Safe Transport of Radioactive Material [25].

MONITORING, INSPECTION AND MAINTENANCE FOR AGEING MANAGEMENT OF TRANSPORT PACKAGES

6.17. For packages intended for repeated use or intended to be used for shipment after storage, ageing effects relevant to the safety of the package should be monitored by periodic inspection and pre-shipment inspection.

6.18. For packages intended for repeated use or intended to be used for shipment after storage, appropriate monitoring should be conducted to ensure that the impacts of ageing effects on the safety of the package are within the acceptance criteria defined in the package design safety report. If the acceptance criteria are exceeded, then corrective maintenance should be undertaken, as defined in the maintenance programme.

6.19. A programme should be prepared at the design stage for systematic integration of monitoring, inspection and maintenance related to ageing. This should be reflected in the package design safety report (i.e. in the sections dealing with ‘MAINTENANCE’ and ‘PACKAGE OPERATIONS’), as applicable. It should then be implemented by the organization in charge of maintenance and/or by the owner or user of the packaging, as relevant.

Packagings intended for repeated use

6.20. The maintenance of packagings intended for repeated use should consist of pre-shipment and periodic inspections to confirm that the safety functions of the package continue to be fulfilled.

Pre-shipment inspection of packages

6.21. This inspection should verify that the package is prepared as designed and ready for shipment in compliance with the applicable requirements of the Transport Regulations. The pre-shipment inspection should be performed by the consignor of the package (or by another organization on behalf of the consignor).

6.22. The pre-shipment inspection should be defined in the package design safety report (i.e. the sections dealing with ‘PACKAGE OPERATIONS’ or ‘MAINTENANCE’, as applicable). The pre-shipment inspection results should be retained by the consignor of the package (with copies provided to other responsible parties, as appropriate) in accordance with its management system. These records should be used as part of the evaluation of ageing effects.

6.23. Pre-shipment inspections for detecting ageing effects may include the following:

(a) Visual inspection: To detect ageing effects on external surfaces of the package (e.g. corrosion, deterioration of painting, cracks, deformation).

(b) Leaktightness checks: Where appropriate, the containment boundary should be checked and the lid seal (O-ring) replaced, if necessary.

(c) Dose rate measurements: To detect ageing effects on the shielding performance.

(d) Checks for subcriticality: For fresh fuel packages, ageing effects on the components to remain the subcriticality(deformation, occurrence of a crack, corrosion, peeling off of neutron absorber) can be detected through a visual check before loading of the radioactive contents.

(e) Temperature measurements: Abnormalities in the package surface temperature and/or surface temperature distribution may indicate deterioration of heat transfer function due to ageing effects (e.g. a loss or a property change of heat conducting medium, a loss or a change of thermal path).

(f) Lifting attachments inspections (e.g. visual inspection, loading test): Potential ageing effects on lifting attachments may be detected when the package is lifted.

Periodic inspection of packaging

6.24. These inspections are periodically conducted, either on the empty packaging or the package containing radioactive contents, depending on the purpose of each inspection item, to confirm that safety functions continue to be fulfilled. Depending on the type of the package, the inspection activities and inspection intervals may be determined through a systematic analysis, such as failure modes and effects analysis.

6.25. Periodic inspections should be performed by the organization in charge of maintenance, on behalf of the owner or the user of the packaging. These inspections should include the items identified in the package design safety report (i.e. in the section dealing with ‘MAINTENANCE’).

6.26. Depending on the package design, periodic inspections for detecting ageing effects may include the following:

(a) Visual inspection, to detect ageing effects on accessible packaging component surfaces (e.g. corrosion, coating defects).

(b) Non-destructive testing (other than visual testing), to detect the existence, initiation and/or propagation of cracks in packaging components, or a reduction in the thickness of components due to ageing.

(c) Leaktightness checks, to detect ageing effects on the lid seals and O-rings, where appropriate. Seals and O-rings should be replaced, if necessary, after a given duration or given number of transport operations (i.e. preventive maintenance), including transport as an empty package, depending on the temperature conditions, to avoid ageing effects on the leaktightness of the package.

(d) Checks for subcriticality for spent fuel packages, to detect ageing effects on the basket structure by dimensional measurements or calibre test (through gauges), and inspections for cracks and other defects The neutron absorber depletion can be calculated based on the records of transport operations, and the general condition of neutron absorbers may be monitored by visual inspection;

(e) Operational checks, to detect ageing effects based on the scheduled replacement of movable components such as valves.

(f) Lifting attachment inspection (e.g. visual inspection, loading test), non-destructive testing may be performed on the attachments, including weld joints, when necessary.

(g) Thermal performance inspection, to detect ageing effects on components related to heat dissipation from the tendency of the temperature measurement inspections for each transport, or by periodic thermal tests.

(h) Shielding performance measurement, to detect ageing effects on shielding components from the tendency of the dose rate inspections for each transport, or direct measurements by using radioactive contents in a periodic test.

(i) Pressure test, to detect ageing effects on pressure retaining components.

(j) Inspection and/or destructive testing of analogues, where it is undesirable or impractical to examine a package component it may be possible to use an analogue (an equivalent or representative component) for periodic inspection and/or non-destructive and/or destructive testing. The condition of the analogue should be representative of the condition of the package component because the analogue should be subjected to the same transport conditions (e.g., impacts, vibrations, and temperature variations) as the package component during shipments. For example, an impact limiter that consists of polyurethane foam fully enclosed within a steel shell could be represented by a separate component of a similar design, made of the same foam and steel, that is carried on the same conveyance as the package. The representative component could be inspected and tested in place of the actual impact limiter.

Packagings intended to be used for shipment after storage

6.27. The ageing management programme for packages intended to be used for shipment after storage should be used to determine the associated maintenance programme, and the operating and maintenance instructions, which should include the following:

(a) Pre-shipment inspection of package before the first shipment (or first loading) before storage;

(b) Reception inspection at the storage facility;

(c) Monitoring programme during storage;

(d) Pre-shipment inspection before the shipment after storage.

These inspections should not be limited to the detection of the ageing effects but should also confirm transportability after storage (i.e. conformance to these inspections during storage demonstrates the compliance with the Transport Regulations to ensure that the safety functions of the package have been maintained (i.e. without any adverse ageing effects) and the package is ready for transport).

6.28. The recommendations provided in paras 6.29–6.44 mostly relate to packages loaded with spent fuel.

Pre-shipment inspection of package before the first shipment (or first loading) before storage

6.29. This pre-shipment inspection should be in accordance with the same provisions as described in paras 6.21 and 6.22.

6.30. (deleted)

6.31. Typical pre-shipment inspection activities are listed in para. 6.23; however, in this case the purpose is not to identify ageing effect but to record the initial package condition.

Receipt inspection of package at the storage facility:

6.32. The primary purposes of this inspection are (i) to verify that the package has been transported without being subject to any event that would affect its safety functions and (ii) that it complies with the storage specifications. This inspection should provide a record of the initial conditions of the package to be stored. The results should be compared with the results of the pre-shipment inspections.

6.33. The receipt inspection at the storage facility should be performed by the operating organization of the storage facility, based on the information from the consignor of the shipment before storage, the packaging owner and the owner of the radioactive contents as appropriate.

6.34. The receipt inspection should be included in the relevant parts of the package design safety report (i.e. the sections dealing with ‘PACKAGE OPERATIONS’ or ‘MAINTENANCE’, as applicable).

6.35. The receipt inspection results should be retained by the operating organization of the storage facility and the packaging owner and the owner of the radioactive contents, in accordance with regulatory requirements and the management systems. The results should be made available to other relevant interested parties.

Monitoring programme during storage

6.36. Monitoring activities of the package during storage might cover activities described in paras 6.32-6.35 for the receipt inspection of package at the storage facility and it is not necessary for them to be two completely independent processes. Monitoring during storage may be conducted continuously, or periodically at intervals that are commensurate with the importance to safety. On the basis of an appropriate justification, monitoring may be conducted on a representative sample of packages of the same design, stored at the same location. The practicability of monitoring (e.g. in high dose rate areas or areas that are otherwise difficult to access) should also be considered.

6.37. The programme of monitoring during storage should be implemented by the operating organization of the storage facility (or by another organization of behalf of the operating organization), based on the information from the packaging owner and the owner of the radioactive contents as appropriate.

6.38. The storage facility should be operated in compliance with regulatory requirements, and should take into account the maintenance programme specified in the package design safety report.

6.39. The results of the receipt inspection, if applicable, should be retained by the operating organization of the storage facility, the packaging owner and the owner of the radioactive contents, in accordance with regulatory requirements and the relevant management systems. The results should be made available to other relevant interested parties.

6.40. The programme of monitoring during storage may include the following:

(a) Visual inspection, to detect ageing effects on the accessible packaging component surfaces.

(b) Non-destructive testing (other than visual inspection), to detect the existence, initiation or propagation of cracks in packaging components, or reduction in thickness of component due to ageing.

(c) Inter-lid pressure monitoring, which is conducted continuously or intermittently, and may substitutes the leaktightness inspection of lid seals. If no anomaly is detected, this demonstrates that the leaktightness of lid seals has been maintained, and consequently the atmosphere of the cavity has been maintained. Pressure transducers or pressure switches are used for monitoring the pressure between the lids or the metal seals. Transducers should be periodically calibrated.

(d) Dose rate measurements on the surface of the package or around the package, which may be performed continuously or intermittently.

(e) Checks for subcriticality, which are normally undertaken through a combination of visual inspections and temperature measurements. If there is no evidence of excessive mechanical impact to the package, identified during the visual inspection, there should be no change of the packaging configuration, including the fuel basket. If there is no abnormal change in package temperature, this indicates that the heat dissipation performance of the package is maintained as designed and there should be no change of the packaging configuration, including the fuel basket.

(f) Temperature measurement inspection, which may be performed continuously or intermittently. Ageing effects on components related to heat dissipation can be detected based on a history of the temperature change and the decay heat generated by the radioactive contents.

(g) Depending on the type of radioactive content stored, the monitoring programme could rely on the inspection prior to storage, use of test or research results and safety analyses to demonstrate that the radioactive content is maintained during storage. In addition, indirect monitoring from other inspections may be used for early detection of a potential problem with radioactive contents, whenever possible. If no significant event affecting the package occurs or is detected during storage, changes in the condition of the contents that could affect the safety of the package are not to be expected.

Pre-shipment inspection of package intended for shipment after storage

6.41. The same inspection methods as described in paras 6.29–6.31 should be conducted. Some types of inspection can be conducted directly, while others (e.g. cavity pressure, subcriticality and radioactive contents) should be substituted by records of visual inspection, inter-lid pressure monitoring, and temperature measurement during storage. Such substitutions should be carefully justified.

6.41bis. Specifically, if the following points are confirmed, it can be judged that no abnormal change in the condition of spent fuel occurs [11]:

(a) Moisture is removed and inert gas is filled in a way that satisfies the design condition during preparation of the dual purpose cask packages in the power plant.

(b) Dual purpose cask packages pass the inspection of contents for transportation from the power plant to the storage facility, and there are no abnormal external forces added during transportation.

(c) There have been no incidents that may damage the integrity of the spent fuel during storage.

(d) The inert atmosphere of the dual purpose cask has been maintained during storage.

Consequently, when the dual purpose cask packages are shipped from the storage facilities, especially if there is no fuel reloading equipment, the inspection of the contents during the pre-shipment inspection can be substituted by the documents that confirm the listed items.

6.42. The pre-shipment inspection of packages for shipment after storage should also refer to the results from all the inspections and monitoring listed in paras 6.29–6.40.

6.43. If packages are loaded and stored in the same facility (or in separate facilities on the same site, i.e. no off-site transport is conducted before storage), items included in paras 6.29–6.35 will not be necessary. However, in such cases, inspections to confirm the safety of the packages (e.g. after loading, before movement) should be conducted. The content of these inspections is similar to those described in paras 6.29–6.31 and (as appropriate) 6.36–6.40.

7. THE ROLE OF THE COMPETENT AUTHORITY IN AGEING MANAGEMENT AND MAINTENANCE OF TRANSPORT PACKAGES

7.1. The owner and user of the packaging is subject to the supervision of the competent authority. When necessary, the competent authority may make specific arrangements for the supervision of ageing management and maintenance programmes for transport packages — in accordance with the characteristics and conditions of use of the packages — and organize compliance inspection accordingly, including on-site.

7.2. The compliance inspection by the competent authority of the ageing management and maintenance programmes for transport packages should consider the following:

(a) List of packagings (model, manufacturer, type, serial numbers);

(b) The requirements of the Transport Regulations, as applicable;

(c) The ageing management programme;

(d) Package operations and their impact in ageing mechanisms;

(e) The maintenance programme and maintenance instructions for packages, with a focus on safety relevant components and the fulfilment of safety functions;

(f) The management system (e.g. personnel training, material and equipment, suppliers, documentation);

(g) Application of the radiation protection programme (see para. 302 of the Transport Regulations) to ageing management and maintenance.

Specific examples of inspection checklists can be found in IAEA Safety Standards Series No. SSG-78, Compliance Assurance for the Safe Transport of Radioactive Material [26]. These can be used as examples to develop specific ageing and maintenance management checklist.

7.3. The manufacture of transport packages (including the production of spare parts) should also be subject to surveillance by the competent authority.

7.4. A package design can be used in countries different from that of the designer or the approval authority (country of origin). Consequently, maintenance operations and ageing management are not necessarily performed in the country of origin of the package. The relevant competent authorities[12] should coordinate their activities to ensure the effective surveillance of ageing management and maintenance programmes.

8. ADMINISTRATIVE MATTERS IN RELATION TO THE AGEING MANAGEMENT AND MAINTENANCE OF TRANSPORT PACKAGES

8.1. Paragraph 802 of the Transport Regulations states that competent authority approval is required for the designs of certain types of package (i.e. Type B(U), Type B(M), Type C packages and packages containing fissile material or 0.1 kg or more of uranium hexafluoride), regardless of their intended use.

8.2. Paragraph 801 of the Transport Regulations states:

> "For *package designs* where it is not required that a *competent authority* issue a certificate of *approval*, the *consignor* shall, on request, make available for inspection by the relevant *competent authority*, documentary evidence of the compliance of the *package design* with all the applicable requirements."

8.3. Para. 613A of the Transport Regulations requires the consideration of the ageing mechanisms in the design of a package. These considerations should be included in the package design safety report as stated in SSG-66 [3].

8.4. For the package design approvals for Type B(U), Type B(M) and Type C packages that are to be used for shipment after storage, ageing mechanisms are required to be considered in the safety analysis and the operating and maintenance instructions (see para. 809(f) of the Transport Regulations). In addition, for such packages, a gap analysis programme is also required (see para. 809(k) of the Transport Regulations).

8.5. Paragraph 501 of the Transport Regulations states:

> "Before a *packaging* is first used to transport *radioactive material*, it shall be confirmed that it has been manufactured in conformity with the *design* specifications to ensure compliance with the relevant provisions of [the Transport Regulations] and any applicable certificate of *approval*."

The package designer should supply the necessary manufacturing documentation of the packaging to the owner of the packaging. The owner of the packaging should supply further that documentation to the user of the packaging. This may include a written certification that the packaging complies with all manufacturing and test requirements, as specified by the owner (or its delegate), and the copies of quality records, results of manufacturing inspections, 'as built' drawings and certifications.

[12] https://gnssn.iaea.org/main/GlobalTransportNetworks/Pages/CompetentAuthorities.aspx

8.6. To fulfil para. 502 and para. 503 of the Transport Regulations, a pre-shipment inspection (see Section 6 of this Safety Guide) is required to be conducted to demonstrate compliance with the applicable requirements.

8.7. Results of manufacturing inspections, pre-shipment inspections and inspections during maintenance should be kept by the designer, owner or user of the package, and the packaging manufacturer, as applicable, to demonstrate that the safety functions are maintained.

8.8. In preparation for the pre-shipment inspections after extended storage, all results of the previous inspections and monitoring should be maintained by the organization responsible for the storage of the package, and delivered to the user of the package responsible for the shipment after storage.

8.9. If modifications are made to the package design, a review should be performed by the package designer of possible changes that could affect the consideration of ageing mechanisms. If necessary, an ageing management review should be completed by package designer for the affected components.

8.10. A transport package design approval is usually renewed by the relevant competent authorities on a periodic basis, depending on the period of validity of the certificate of approval. Before each application for renewal, the applicant should evaluate changes in the Transport Regulations, any advances in technical knowledge and feedback from operating experience. Depending on the results of this evaluation, an application for modification of the package design may be needed in addition to the renewal of the certificate of approval.

9. INTERFACES IN RELATION TO AGEING MANAGEMENT AND MAINTENANCE OF TRANSPORT PACKAGES

INTERFACES BETWEEN TRANSPORT AND STORAGE

9.1. The storage of packages is often covered by separate regulations (i.e. in addition to the Transport Regulations) in Member States. In the case of shipment after storage, there are important interfaces to be considered between transport and storage that should be addressed in order to maintain the transportability of the package. In most cases, the approach to ageing management may be common; however, evaluations may differ between transport and storage, because the environment and loading conditions are different.

9.2. The operating organization of the storage facility should take into account the ageing management and maintenance programme included in the package design safety report (i.e. in the sections on ‘AGEING CONSIDERATIONS’ and ‘MAINTENANCE’), in the development of its own ageing management programme.

INTERFACES BETWEEN THE COUNTRY OF ORIGIN, THE COUNTRY OF USE AND THE COUNTRY OF STORAGE

9.3. For shipment after storage of a package subject to unilateral approval, if this approval is withdrawn or not renewed in the country of origin of the package design, the competent authority where the package is stored may consider issuing a new package design approval, as described in para. 840.3 of SSG-26 (Rev.1) [2].

9.4. The applicant for package design approval in the country of storage should obtain as much of the relevant information as possible from the package designer and/or the competent authority of the country of origin to fully understand the contents and background of the original application. This should include information on ageing considerations, maintenance (e.g. monitoring during storage), requirements for shipment after storage and the gap analysis programme.

9.5. Before issuing the package design approval, the competent authority of the country of storage should obtain information on the safety assessment from the competent authority of the country of origin of the design.

9.6. Irrespective of the status of the original package design approval, the following should be considered:

(a) The packaging owner, the user of the package and the operator of the storage facility in the country of storage should implement, as relevant, the provisions of the ageing management programme and maintenance programme included in the package design safety report supporting the package design approval issued by the competent authority in the country of origin.
(b) The competent authority of the country of storage should verify the implementation of the ageing management programme and maintenance programme through inspections.
(c) The owner of the packaging and the owner of the radioactive contents should periodically provide the competent authority of the country of storage with a gap analysis based on the gap analysis programme provided by the package designer in the country of origin. If the periodic gap analysis identifies non-compliances in the safety justifications of the package design approval, the owner of the package should ask the package designer in the country of origin for an update of the relevant safety justifications and, if applicable, should request a revision of the design approval.

9.7. For shipment of a package subjected to unilateral approval other than shipment after storage, an approach similar to the one described in paras. 9.3–9.6, as applicable, should be used.

APPENDIX I

EXAMPLES OF APPROACHES TO CONSIDER AGEING MECHANISMS IN PACKAGE DESIGN

IDENTIFICATION OF AGEING EFFECTS

I.1. Based on the service life of the package and the environmental and loading conditions (see paras 3.2–3.6), the potential ageing mechanisms for each packaging component and material should be selected. The results should be summarized in the package design safety report (i.e. in a table in the section on ‘AGEING CONSIDERATIONS’), to show the relationship between components and materials and the potential ageing mechanisms to be considered.

I.2. Table I.1 shows examples of a variety of packages and possible ageing mechanisms, in which yes (Y) indicates that the mechanism should be considered. In all cases, an evaluation of the specific package design should be performed by the package designer, taking into account the environmental and operational conditions.

I.3. Additional points to be noted are:

(a) “Y” (yes) is used to indicate all ageing mechanisms that are possible. If a mechanism can be excluded through subsequent evaluation, the reason for this should be stated in the package design safety report (i.e. in the section on ‘AGEING CONSIDERATIONS’). Any mechanisms excluded for the material can be left blank or marked as “N” (no).

(b) Ageing mechanisms are time and stressor dependent phenomena; hence the operation duration and loading conditions are essential elements to be considered. For packagings intended for repeated use, the cyclic loadings induced from the maximum radioactive contents and number of cycles should be considered.

TABLE I.1 EXAMPLE SCOPE SETTING TABLE FOR AGEING MECHANISMS

Type of package	Component	Material	AGEING MECHANISM													
			General corrosion	Crevice corrosion	Pitting corrosion	Stress corrosion cracking	Microbiologically influenced corrosion	Creep	Fatigue	Hydride reorientation	Delayed hydride cracking	Mechanical overload	Radiation embrittlement	Radiolysis	Stress relaxation	Thermal ageing
Excepted	Outer shell	Cardboard														

Type A	Inner shell	Steel (can)	Y													
	Buffer cushion	Urethane foam														
Type IP **Type A** **(Steel drum)**	Can body and bottom plate	Carbon steel	Y	Y	Y											
	Lid	Carbon steel	Y	Y	Y											
	Lid band	Zinc plated steel	Y	Y												
	Lid band clamping screw	Carbon steel	Y	Y	Y											
Type IP **Type A** **(Metal container)**	Outer panel	Stainless steel		Y	Y	Y										
	Inner container	Stainless steel		Y	Y	Y										
	Shielding	Lead														
	Damping systems	Urethane foam														
	Screws	Carbon steel	Y		Y											
	Lids	Carbon steel	Y	Y	Y											
Type B(U) **Type B(M)** **Type C**	Outer shell	Stainless steel		Y	Y	Y										
	Inner shell	Low-alloy steel	Y	Y	Y								Y			
	Lid	Stainless steel		Y	Y	Y										
	Lid bolt	Low-alloy steel	Y	Y	Y	Y									Y	
	Screws	Carbon steel	Y		Y											
	Lid seal	elastomeric polymer											Y	Y	Y	
	Gamma shielding	Lead														
	Thermal conductor	Copper						Y	Y						Y	Y
	Trunnions	Stainless steel		Y	Y	Y			Y							
	Shock absorbers	Plywood					Y							Y		Y
	Casing of shock absorbers	Stainless steel		Y	Y	Y										
UF_6	Overpack	Stainless steel		Y	Y	Y										
	Screws	Carbon steel	Y		Y											
	Thermal insulator	Urethane form														Y
	Valve and plug	Alloy	Y	Y		Y			Y							
	Cylinder shell	Carbon steel	Y	Y	Y	Y										
	Skirts	Carbon steel	Y	Y	Y											
UO_2 **(Type AF, Type IPF)**	Overpack	Stainless steel		Y	Y	Y										
	Lid	Stainless steel		Y												
	Screws	Carbon steel	Y		Y											
	Lid seal	Elastomeric polymer														
	Outer shield	Lead														
	Inner can	Stainless steel		Y	Y	Y										
	Thermal insulator	Foam														
	Neutron absorber	B-Al or B-Stainless steel														
Fresh Fuel **(Type AF, Type IPF, B(U)F)**	Outer shell	Stainless steel		Y	Y	Y										
	Inner shell	Low-alloy steel	Y	Y	Y											
	Lid	Stainless steel		Y	Y											
	Screws	Carbon steel	Y		Y											
	Lid bolt	Low-alloy steel	Y	Y	Y										Y	
	Lid seal	Aluminium/Inconel	Y	Y	Y										Y	
	Fuel cladding	Zircaloy														
	Thermal insulator	Foam														

	Neutron absorber	B-Al or B-Stainless steel														
	Trunnions	Stainless steel		Y	Y	Y			Y							
	Shock absorbers	Plywood					Y									
	Casing of shock absorbers	Stainless steel		Y	Y	Y										
Dual purpose cask **Spent Fuel** **(Type B(U)F, Type B(M)F, Type CF)**	Outer shell	Stainless steel		Y	Y	Y	Y						Y			
	Inner shell	Low-alloy steel	Y	Y	Y								Y			Y
	Lid	Stainless steel		Y	Y	Y	Y						Y			
	Screws	Carbon steel	Y	Y	Y				Y				Y		Y	
	Lid bolt	Low-alloy steel	Y	Y	Y				Y				Y		Y	
	Lid seal	Aluminium alloy	Y	Y	Y			Y					Y		Y	Y
	Additional lid seal	Elastomeric polymer											Y	Y		Y
	Gamma shielding	Lead	Y					Y								
	Neutron shielding	Resin											Y	Y		Y
	Thermal path basket	Copper						Y	Y						Y	Y
	Fuel basket	Borated aluminium						Y					Y	Y		Y
	Spent fuel cladding	Zircaloy	Y					Y		Y	Y	Y	Y			Y
	Trunnions	Stainless steel		Y	Y	Y			Y							
	Shock absorbers	Plywood					Y							Y		
	Casing of shock absorbers	Stainless steel		Y	Y	Y										

EVALUATION OF AGEING EFFECTS

I.4. The typical items of concern for ageing effects are listed below:

(a) Changes in mechanical strength such as allowable stress, fracture toughness caused by irradiation, and thermal loading;

(b) Creep rate and quantity, by heat, stress, and time;

(c) Number and intensity of cyclic stresses with regard to fatigue assessment;

(d) Initiation of stress corrosion cracking due to stress, environmental, and material combination;

(e) Reduction in the thickness or localized penetration of the component due to corrosion;

(f) Stress relaxation in the lid bolt and metal gasket due to temperature, stress, and time;

(g) Reduction in the sealing force in the elastomer O-ring due to temperature and irradiation;

(h) Depletion of the hydrogen content of neutron shielding material due to temperature;

(i) Depletion of the ^{10}B content of neutron shielding material due to neutron irradiation;

(j) Initiation of the hydride reorientation due to stress and temperature loading.

I.5. Based on the results obtained from the first step of evaluation (e.g. quantitative changes in material properties, material strength), the consequences on the safety functions of the package due to ageing mechanisms should be assessed by the package designer in the package design safety report (i.e. in the section on 'AGEING CONSIDERATIONS'). If the consequences are negligible (or within an allowable range), no measures to control the ageing mechanism need to be taken. The severity of the consequences should be reflected in maintenance programmes, in accordance with a graded approach. Typical examples of consequences of ageing mechanisms on safety functions are as follows:

(a) For the structural components, changes in materials caused by irradiation might lead to a decrease in the allowable stress or embrittlement of the structural components, which could result in a collapse of the elements sharing safety functions, for example as follows:

  (i) The collapse of components consisting of a containment boundary (e.g. a shell, a bottom plate, lid(s), lid bolts and seal(s)), leading to the loss of containment;

  (ii) The collapse or deformation of a fuel basket, affecting criticality safety;

  (iii) Deformation or breakage of a fuel basket plate, disrupting heat conduction through the plate, and thereby degrading heat dissipation;

  (iv) The collapse of a trunnion during handling or transport, leading to a drop of the package, resulting in further damage and degradation of the safety functions of the package;

(b) The breakage of thermal conductor (copper plates) in the neutron shielding layer, disrupting heat conduction through the plate, and thereby degrading heat dissipation and inducing a potential increase of the temperature of the fuel basket and consequently a decrease in mechanical properties.

(c) The depletion of ^{10}B contained in neutron absorber material due to neutron irradiation, affecting criticality safety.

(d) The loss of hydrogen contained in neutron shielding due to heat, degrading the shielding and increasing the external dose rate around the package.

(e) The rupture of spent nuclear fuel rod cladding, resulting in increasing internal pressure in the package cavity, potential change in the physical configuration of the fuel, changes to the cover gas composition and an increase in the radioactive material directly contained in the package containment system.

DESIGN APPROACHES TO PREVENT ADVERSE AGEING EFFECTS

I.6. There are four typical design approaches to prevent ageing mechanisms causing adverse effects on package performance, as follows:

(a) Selecting component materials that do not exceed thresholds for ageing effects;

(b) Replacing or refurbishing components before ageing effect thresholds are exceeded;

(c) Designing package performance parameters not to exceed ageing effect thresholds, taking into account environmental and operational conditions;

(d) Ensuring that the package design is based on the properties of aged component materials.

A threshold parameter for preventing adverse ageing effects on each package component should be determined taking into account the properties of aged material.

Selecting component materials that do not exceed thresholds for ageing effects

I.7. This is the most basic approach for using the material within the range to avoid material property change. Examples of this approach are as follows:

(a) Selecting a material with a neutron irradiation threshold for changes to mechanical properties greater than the cumulative neutron irradiation during operation;

(b) Selecting a material that does not initiate creep deformation under stress and temperature during operation;

(c) Selecting a material without initiation of stress corrosion cracking under specific stress and environmental conditions during operation.

I.8. The package designer should include restrictions on the selection of components and materials in the package design safety report (i.e. as design requirements in the sections on 'SPECIFICATION OF THE PACKAGING', and 'SPECIFICATION OF THE CONTENTS' and the appropriate justification in the section on 'AGEING CONSIDERATIONS').

Replacing or refurbishing components before ageing effect thresholds are exceeded

I.9. Components should be replaced, as appropriate, before their performance is degraded to the extent that predetermined ageing thresholds. This approach is applicable to a component designed to be replaced or refurbished during either operation or maintenance of empty packaging. The thresholds should be set at levels at which the safety functions of the package might be affected, or else at a detectable value determined by the evaluation of ageing effects. The package designer should provide instructions that are reflected in maintenance programmes, for detecting ageing prior to thresholds being exceeded, and for replacing or repairing components, for example as follows:

(a) Replacing a component (e.g. an elastomer O-ring for the lid seal) before the acceptance criterion (e.g. leak rate measured at the leaktightness test) or the allowable number of transport operations, as determined by the evaluation of ageing effects, is exceeded;

(b) Replacing a metallic gasket for the second lid of a package intended to be used for transport after storage of spent fuel, after a drop of the inter-lid pressure is detected, and the integrity of metallic gasket for the primary lid is proven;

(c) Replacing components (e.g. trunnions) when predetermined criteria are reached (e.g. a cumulative number of lifting operations, as predetermined by the fatigue analysis);

(d) Refurbishment actions (e.g. repainting).

These actions should be included by the package designer in the package design safety report (i.e. as replacement and refurbishing operations in the sections on ‘PACKAGE OPERATIONS’, and ‘MAINTENANCE’, as applicable, and the appropriate justification in the section on ‘AGEING CONSIDERATIONS’).

Designing package performance parameters not to exceed the ageing effect threshold

I.10. Performance parameters to limit ageing effect should be set at a level that would avoid serious deterioration of safety functions. Limits can be set in terms of (but not limited to) fatigue, creep, annealing, embrittlement and/or hydride reorientation.

I.11. Typical performance parameters are cyclic stress, temperature and temperature-dependent stress. The temperature of the package component depends on the rate of dissipation of decay heat from radioactive contents; hence, such decay can also be set as a parameter. Performance parameters should be monitored by the user of the package, on the basis of instructions provided by the designer, to ensure that they are within an acceptable range. Examples of this approach are as follows:

(a) The cyclic stress that occurs in the component is calculated, and should not exceed the fatigue limit of the component material. If the fatigue limit is unlimited, or is so high that it cannot be reasonably exceeded, no further action is necessary. Otherwise, the owner and user of the packaging should, for example, monitor and record the number of transport operations.

(b) In designing the heat dissipation performance of the package, it can be ensured that related parameters (e.g. temperature and stress of the component of concern) do not result in excessive creep in the component material during operation. This should be achieved by restrictions on the radioactive content, to ensure that the heat dissipation rate is in accordance with the maximum value stated in the package design safety report (i.e. in the section on ‘SPECIFICATION OF THE CONTENTS’).

(c) In designing the heat dissipation performance of the package, it can be ensured that related parameters (e.g. temperature of the component of concern) do not result in exceeding the predetermined temperature limit of the component material, to prevent the initiation of ageing (e.g. annealing of embrittlement and hydride reorientation) during operation. This should be achieved by restrictions on the radioactive content, to ensure that the heat dissipation rate is in accordance with the maximum value stated in the package design safety report (i.e. in the section on ‘SPECIFICATION OF THE CONTENTS’).

Package design based on the properties of aged component materials

I.12. A package design may be based on the properties of aged component materials; however, caution should be taken when considering these properties. Such properties are often estimated by exposing materials to very severe environments to accelerate the ageing mechanism and shorten the time of the experiment. Hence, the acceleration method and the extrapolation of the obtained data should be fully justified to ensure that they are representative of appropriate (and not unduly conservative) properties. Some examples of this approach include the following:

(a) Using the allowable stress of the simulated aged material in structural design.

(b) Using the reduced fracture toughness in the evaluation of fracture mechanics.

(c) Using the increased leak rate of an aged metallic gasket in the evaluation of a radioactive release.

(d) Using a depleted hydrogen concentration to represent aged neutron shielding material.

(e) Using a depleted ^{10}B concentration to represent aged neutron absorber material in the design for criticality safety.

APPENDIX II

EXAMPLE STRUCTURE OF AN AGEING MANAGEMENT PROGRAMME FOR TRANSPORT PACKAGES

II.1. The ageing management programme for transport packages should be developed using a structured methodology to ensure a consistent approach in implementing ageing management. The programme should be developed considering all safety relevant components of the package. In practice, ageing mechanisms and effects are studied and managed at the component level. However, the ageing management programme for individual components may be integrated into an ageing management programme at the package level.

II.2. There are generally four types of activity that should be considered in an ageing management programme:

(a) Prevention activities, which prevent ageing effects from occurring (e.g. coating measures to prevent external corrosion of carbon steel overpack components or adequate drying to prevent hydride reorientation in high-burnup cladding alloys).

(b) Mitigation activities, which attempt to slow or reduce the effects of ageing.

(c) Condition monitoring activities to identify the presence and extent of ageing effects (e.g. visual inspection of package surfaces for cracking and sensors that monitor package surface temperatures, inter-lid pressure, or fission gases such as ^{85}Kr).

(d) Performance monitoring activities, which verify the ability of the components to perform their intended safety functions (e.g. periodic radiation monitoring and temperature monitoring).

II.3. Each individual ageing management programme developed to support the ageing considerations may contain the elements listed in paras II.4–II.16 (adapted from Table 2 of SSG-48 [4]). Examples of ageing management programmes and the information needed to develop such programmes are provided in Refs [7–10, 12].

THE SCOPE OF THE AGEING MANAGEMENT PROGRAMME

II.4. The scope of the ageing management programme should list the specific components of the package covered by the programme and the safety functions to be maintained. In addition, the specific materials, environmental and operational conditions, ageing mechanisms and effects to be managed should be stated (see paras 3.6 – 3.11).

PREVENTIVE ACTIONS TO MINIMIZE AND CONTROL AGEING EFFECTS

II.5. Preventive actions, including design or manufacture procedures, should be used to sufficiently prevent any ageing effects on components that could affect the safety functions of the package. The preventive actions described should be supported with an analysis and data demonstrating that they will be effective.

DETECTION OF AGEING EFFECTS

II.6. To detect ageing effects before there is a loss of safety function for any packaging component within the scope of the ageing management programme, inspection and monitoring should include the following:

(a) Specification of parameters to be monitored or inspected, taking into account the environmental and operational conditions. The need of monitoring each package may be eliminated by monitoring certain facility parameters (i. e. temperature, humidity).
(b) A method (e.g. visual, volumetric, surface inspection) capable of evaluating the conditions of the component for the specific ageing mechanism or effect.
(c) An adequate frequency of inspections to ensure that safety functions will be maintained.
(d) An identification and a justification of the number of components to be evaluated in each inspection, the extent of the inspection of each component and the criteria for selection of the component for inspection. For inaccessible components, alternative measures to assess their condition should be provided.
(e) A documentation of the results including descriptions of observed ageing effects, and supporting diagrams, photographs or videos. Any specific methods to be used for data acquisition and documentation, including any applicable codes and standards should be referenced. The documentation should be archived in an adequate manner in order to be retrievable.

MONITORING AND IDENTIFYING TRENDS OF AGEING EFFECTS ON TRANSPORT PACKAGES

II.7. The parameters related to the condition and safety performance of the package should be identified, providing a clear link to the ageing mechanisms listed in the scope of ageing management programme and descriptions of the capability and means of identifying ageing effects or potential degradation before a loss of the safety function (See Section 3). The parameters should be used as part of the following:

(a) Monitoring the effectiveness of measures that prevent or mitigate ageing;
(b) Monitoring the performance of components as an indirect indicator of degradation;
(c) Detecting, through direct inspection, the presence and severity of conditions or discontinuities that might have an effect on the function of the components.

II.8. A description of the extent of the effects of ageing should be provided including the evaluation of the results of examinations and inspections. This should include an evaluation of the results against the acceptance criteria and an analysis of trends in the identified ageing effects. The evaluation should consider the rate of degradation to ensure the timing of the next scheduled inspection will occur before a loss of safety functions, taking into account any trends identified in the ageing mechanisms and their effects.

MITIGATION OF AGEING EFFECTS

II.9. Mitigating measures, including design or manufacture procedures, should be used to mitigate the rates of ageing of package components. These measures should be supported by data and an analysis that demonstrate that the measures are effective.

II.10. Examples of mitigating measures include maintenance, repair and replacement actions to mitigate detected ageing effects and/or degradation of the components.

ACCEPTANCE CRITERIA

II.11. The acceptance criteria, against which the need for corrective action is evaluated, should ensure that the component safety functions are maintained. The acceptance criteria should be appropriately justified and can be subject to adjustment based on new technical knowledge. The acceptance criteria should be based on the information included in the package design safety report.

CORRECTIVE ACTIONS

II.12. Corrective actions should include the measures to be taken when the acceptance criteria are not met, and which address the ageing effects. The corrective actions should also aim to prevent the recurrence of the condition. Corrective actions should be adequately and effectively performed, with care taken to ensure that such actions do not have an adverse effect on the components.

II.13. The corrective actions should be described in procedures prepared and controlled in accordance with the management system, and should be based on the package design safety report.

OPERATING EXPERIENCE FEEDBACK

II.14. The ageing management programmes for transport packages should be updated and revised to take into account relevant operating experience, including the following:

(a) Technical knowledge and corrective action reports, from inside the organization and from similar organizations;
(b) Safety bulletins from suppliers;
(c) Communications from regulatory bodies.

QUALITY MANAGEMENT

II.15. This part of the ageing management programme is intended to verify that preventive actions are adequate and that appropriate corrective actions have been completed and are effective. The confirmation process should describe or reference procedures to the following:

(a) A process for verifying that preventive actions are adequate and appropriate;

(b) A process to verify the effective implementation of corrective actions;

(c) Indicators to facilitate evaluation and improvement of the ageing management programme;

(d) Monitoring for adverse trends due to recurring or repetitive findings or observations.

II.16. The ageing management programme should include administrative controls in respect of the following:

(a) Instrument calibration and maintenance;

(b) Qualification of staff performing inspections (e.g. organization, training and certificates of competence);

(c) Retention of records and document control, in accordance with the management system.

APPENDIX III

ROLES AND RESPONSIBILITIES OF INTERESTED PARTIES IN RELATION TO AGEING MANAGEMENT AND MAINTENANCE OF TRANSPORT PACKAGES

PACKAGE DESIGNER

III.1. The package designer is the person or organization that takes responsibility for the complete package design. For each package design there should be only one package designer, who should issue the package design safety report as described in SSG-66 [3].

III.2. Before the first use of the packages that require competent authority approval, their package design must be approved. The package designer is usually the applicant for the approval of the package design.

III.3. In issuing the package design safety report [3], the sections on ‘AGEING CONSIDERATIONS’ and ‘GAP ANALYSIS PROGRAMME’ should be based on the specification of the package (i.e. as defined in the sections on ‘SPECIFICATION OF THE CONTENTS’, ‘SPECIFICATION OF THE PACKAGING’, and on the maintenance programme defined in the sections on ‘PACKAGE OPERATIONS’ and ‘MAINTENANCE’).

III.4. The package designer should interact with the relevant interested parties regarding manufacturing, use and maintenance and the operator of the storage facility, if applicable, in order to gather feedback. For transport packages containing spent fuel, the package designer should interact also with the fuel vendors to gather the relevant information regarding the changes in the behaviour of the spent fuel assemblies.

III.5. The package designer should update the package design safety report, as necessary. This may include the ageing management and maintenance programmes and the gap analysis programme, as applicable.

MANUFACTURER OF THE PACKAGING

III.6. The manufacturer of the packaging should be responsible for the compliance with the provisions defined by the package designer in the package design safety report for the use of materials, technology and processes.

III.7. Before starting the manufacturing, the manufacturer should ensure that the procedures to be applied are qualified to meet the provisions of the package designer, and are conducted in accordance with their management system.

III.8. In the case of non-compliances with the applicable design documents and design modifications, the role of the manufacturer is even more relevant. The manufacturer should collaborate with the package designer to assess the impact of any such variations.

OWNER OF THE PACKAGING

III.9. The owner of the packaging should implement the actions that are necessary to ensure compliance of the packaging with the provisions in the package design safety report, and of the package design approval, if applicable. For that purpose, the owner of the packaging should:

(a) Liaise with the organization in charge of maintenance,

(b) Maintain the records from inspections and maintenance operations;

(c) Conduct the necessary preventive actions and corrective actions in the ageing management programme and the gap analysis programme, as applicable.

III.10. The packaging owner should evaluate the results of the maintenance programme. If non-compliances with the safety justifications in the package design safety report are identified, the owner of the packaging should inform the package designer to review the package design and notify the competent authority, if applicable.

III.11. If the owner of the packaging is not the same as the user of the packaging, the owner should be responsible for supplying the package design safety report to the user.

USER OF THE PACKAGING

III.12. The user of the packaging is usually the consignor of the package. The consignor prepares the shipment of the package in accordance with the requirements of the Transport Regulations. Therefore, the user of the packaging should be responsible for ensuring that the packaging is in a serviceable condition prior to shipment.

III.13. Generally, the user of the packaging is the owner of the packaging and therefore should assume the responsibilities described for the owner in paras III.9–III.11.

III.14. When the user of the packaging is not the owner of the packaging and the owner is responsible for the implementation of the maintenance programme, the user should request from the owner of the packaging all relevant records from the ageing management and maintenance programmes.

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