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Meeting Regulatory Requirements

KHNP Training Program

Module 5: Transportation of Nuclear Materials

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Introduction

- Regulations of all countries are based upon the IAEA safety standards.
  - The U.S. regulations are maintained aligned with the IAEA standards.
- This presentation will follow the outline of the U.S. regulations
  - In particular, 10CFR71 (Packaging and Transportation of Radioactive Material).
  - Key points of 10CFR71 will be discussed, not a complete coverage of the code.
- Applying the IAEA standards after understanding the U.S. regulations is straight forward.

10CFR71 Structure

- Subpart A--General Provisions (71.0 – 71.11)
- Subpart B--Exemptions (71.12 – 71.16)
- Subpart C--General Licenses (71.17 – 71.25)
- Subpart D--Application for Package Approval (71.31 – 71.39)
- Subpart E--Package Approval Standards (71.41 – 71.65)
- Subpart F--Package, Special Form, and LSA-III Tests (71.71 – 71.77)
- Subpart G--Operating Controls and Procedures (71.81 – 100)
- Subpart H--Quality Assurance (71.101 – 71.137)
- Appendix A to Part 71--Determination of A_1 and A_2

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Subpart A--General Provisions (71.0 – 71.11)

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§ 71.0 Purpose and Scope

- This part establishes:
  - Requirements for packaging, preparation for shipment, and transportation of licensed material
  - Procedures and standards for NRC approval of packaging and shipping procedures for fissile material and for a quantity of other licensed material in excess of a Type A quantity.

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§ 71.3 Requirements for License

- Except as authorized in a general license or a specific license issued by the Commission, or as exempted in this part, no licensee may
  - Deliver licensed material to a carrier for transport; or
  - Transport licensed material.
- What this means is that a license is required.

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§ 71.4 Definitions

- The definitions for terms used in this code are given in this section.
  - Please read this section as a homework assignment

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§ 71.5 Transportation of licensed material

- This section describes the Department of Transportation (DOT) regulations that must also be followed.
- The licensee shall particularly note DOT regulations in the following areas:
  - Packaging--49 CFR part 173: subparts A, B, and I.
  - Marking and labeling--49 CFR part 172: subpart D; and §§ 172.400 through 172.407 and §§ 172.436 through 172.441 of subpart E.
  - Placarding--49 CFR part 172: subpart F, especially §§ 172.500 through 172.519 and 172.556; and appendices B and C.
  - Accident reporting--49 CFR part 171: §§ 171.15 and 171.16.
  - Shipping papers and emergency information--49 CFR part 172: subparts C and G.
  - Hazardous material employee training--49 CFR part 172: subpart H.
  - Security plans--49 CFR part 172: subpart I.
  - Hazardous material shipper/carrier registration--49 CFR part 107: subpart G.

§ 71.5 Transportation of licensed material (cont.)

- The licensee shall also note DOT regulations pertaining to the following modes of transportation:
  - Rail--49 CFR part 174: subparts A through D and K.
  - Air--49 CFR part 175.
  - Vessel--49 CFR part 176: subparts A through F & M.
  - Public Highway--49 CFR part 177 and parts 390 through 397.

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§ 71.10 Public inspection of application

- Applications for approval of a package design under this part, may be made available for public inspection.
- This includes an application to amend or revise an existing package design, any associated documents and drawings submitted with the application, and any responses to NRC requests for additional information.
- This material is available from the U.S. NRC Public Document Room

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Subpart B--Exemptions (71.12 – 71.16)

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§ 71.14 Exemption for low-level materials

- A licensee is exempt from all the requirements of this part with respect to shipment or carriage of the following low-level materials:
  - Natural material and ores containing naturally occurring radionuclides that are not intended to be processed for use of these radionuclides, provided the activity concentration of the material does not exceed 10 times the values specified in Appendix A, Table A-2, of this part.
  - Materials for which the activity concentration is not greater than the activity concentration values specified in Appendix A, Table A-2 of this part, or for which the consignment activity is not greater than the limit for an exempt consignment found in Appendix A, Table A-2, of this part.

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§ 71.14 Exemption for low-level materials (cont.)

- A licensee is exempt from all the requirements of this part, other than §§ 71.5 and 71.88, with respect to shipment or carriage of the following packages, provided the packages do not contain any fissile material, or the material is exempt from classification as fissile material under § 71.15:
  - A package that contains no more than a Type A quantity of radioactive material;
  - A package transported within the United States that contains no more than 0.74 TBq (20 Ci) of special form plutonium-244; or
  - The package contains only LSA or SCO radioactive material, provided--
    - That the LSA or SCO material has an external radiation dose of less than or equal to 10 mSv/h (1 rem/h), at a distance of 3 m from the unshielded material; or
    - That the package contains only LSA-I or SCO-I material.

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§ 71.15 Exemption from classification as fissile material

- Individual package containing 2 grams or less fissile material.
- Individual or bulk packaging containing 15 grams or less of fissile material provided the package has at least 200 grams of solid nonfissile material for every gram of fissile material. Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass for solid nonfissile material.
- Low concentrations of solid fissile material commingled with solid nonfissile material, provided that:
  - There is at least 2000 grams of solid nonfissile material for every gram of fissile material, and
  - There is no more than 180 grams of fissile material distributed within 360 kg of contiguous nonfissile material.

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§ 71.15 Exemption from classification as fissile material (cont.)

- Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass of solid nonfissile material.
- Uranium enriched in uranium-235 to a maximum of 1 percent by weight, and with total plutonium and uranium-233 content of up to 1 percent of the mass of uranium-235, provided that the mass of any beryllium, graphite, and hydrogenous material enriched in deuterium constitutes less than 5 percent of the uranium mass.
- Liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2 percent by mass, with a total plutonium and uranium-233 content not exceeding 0.002 percent of the mass of uranium, and with a minimum nitrogen to uranium atomic ratio (N/U) of 2. The material must be contained in at least a DOT Type A package.
- Packages containing, individually, a total plutonium mass of not more than 1000 grams, of which not more than 20 percent by mass may consist of plutonium-239, plutonium-241, or any combination of these radionuclides.

Subpart C--General Licenses (71.17 – 71.25)

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§ 71.17 General license: NRC-approved package

- A general license is issued to any licensee of the Commission to transport, or to deliver to a carrier for transport, licensed material in a package for which a license, certificate of compliance (CoC), or other approval has been issued by the NRC.
- This general license applies only to a licensee who has a quality assurance program approved by the Commission as satisfying the provisions of subpart H of this part.
- This general license applies only to a licensee who--
  - Has a copy of the CoC, or other approval of the package, and has the drawings and other documents referenced in the approval relating to the use and maintenance of the packaging and to the actions to be taken before shipment;
  - Complies with the terms and conditions of the license, certificate, or other approval, as applicable, and the applicable requirements of subparts A, G, and H of this part; and
  - Before the licensee's first use of the package, submits in writing to: ATTN: Document Control Desk, Director, Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, using an appropriate method listed in § 71.1(a), the licensee's name and license number and the package identification number specified in the package approval.
- This general license applies only when the package approval authorizes use of the package under this general license.
- For a Type B or fissile material package, the design of which was approved by NRC before April 1, 1996, the general license is subject to the additional restrictions of § 71.19.

§ 71.21 General license: Use of foreign approved package

- A general license is issued to any licensee of the Commission to transport, or to deliver to a carrier for transport, licensed material in a package, the design of which has been approved in a foreign national competent authority certificate, that has been revalidated by DOT as meeting the applicable requirements of 49 CFR 171.12.
- Except as otherwise provided in this section, the general license applies only to a licensee who has a quality assurance program approved by the Commission as satisfying the applicable provisions of subpart H of this part.
- This general license applies only to shipments made to or from locations outside the United States.
- This general license applies only to a licensee who--
  - Has a copy of the applicable certificate, the revalidation, and the drawings and other documents referenced in the certificate, relating to the use and maintenance of the packaging and to the actions to be taken before shipment; and
  - Complies with the terms and conditions of the certificate and revalidation, and with the applicable requirements of subparts A, G, and H of this part. With respect to the quality assurance provisions of subpart H of this part, the licensee is exempt from design, construction, and fabrication considerations.

§ 71.22 General license: Fissile material

- A general license is issued to any licensee of the Commission to transport fissile material, or to deliver fissile material to a carrier for transport, if the material is shipped in accordance with this section. The fissile material need not be contained in a package which meets the standards of subparts E and F of this part; however, the material must be contained in a Type A package. The Type A package must also meet the DOT requirements of 49 CFR 173.417(a).
- The general license applies only to a licensee who has a quality assurance program approved by the Commission as satisfying the provisions of subpart H of this part.
- The general license applies only when a package's contents:
  - Contain no more than a Type A quantity of radioactive material; and
  - Contain less than 500 total grams of beryllium, graphite, or hydrogenous material enriched in deuterium.
- The general license applies only to packages containing fissile material that are labeled with a CSI which:
  - Has been determined in accordance with paragraph (e) of this section;
  - Has a value less than or equal to 10; and
  - For a shipment of multiple packages containing fissile material, the sum of the CSIs must be less than or equal to 50 (for shipment on a nonexclusive use conveyance) and less than or equal to 100 (for shipment on an exclusive use conveyance).

§ 71.23 General license: Plutonium-beryllium special form material

- A general license is issued to any licensee of the Commission to transport fissile material in the form of plutonium-beryllium (Pu-Be) special form sealed sources, or to deliver Pu-Be sealed sources to a carrier for transport, if the material is shipped in accordance with this section. This material need not be contained in a package which meets the standards of subparts E and F of this part; however, the material must be contained in a Type A package. The Type A package must also meet the DOT requirements of 49 CFR 173.417(a).
- The general license applies only to a licensee who has a quality assurance program approved by the Commission as satisfying the provisions of subpart H of this part.
- The general license applies only when a package's contents:
  - Contain no more than a Type A quantity of radioactive material; and
  - Contain less than 1000 g of plutonium, provided that: plutonium-239, plutonium-241, or any combination of these radionuclides, constitutes less than 240 g of the total quantity of plutonium in the package.
- The general license applies only to packages labeled with a CSI which:
  - Has been determined in accordance with paragraph (e) of this section;
  - Has a value less than or equal to 100; and
  - For a shipment of multiple packages containing Pu-Be sealed sources, the sum of the CSIs must be less than or equal to 50 (for shipment on a nonexclusive use conveyance) and less than or equal to 100 (for shipment on an exclusive use conveyance).

Subpart D--Application for Package Approval (71.31 – 71.39)

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Subpart D--Application for Package Approval

- § 71.31 Contents of application
- § 71.33 Package description
- § 71.35 Package evaluation
- § 71.37 Quality assurance

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§ 71.33 Package description

- Classification as Type B(U), Type B(M), or fissile material packaging
- Gross weight
- Model number
- Identification of the containment system
- Specific materials of construction, weights, dimensions, and fabrication methods
- Identification and volumes of any receptacles containing coolant.

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§ 71.33 Package description - contents

- Identification and maximum radioactivity of radioactive constituents;
- Identification and maximum quantities of fissile constituents;
- Chemical and physical form;
- Extent of reflection, the amount and identity of nonfissile materials used as neutron absorbers or moderators, and the atomic ratio of moderator to fissile constituents;
- Maximum normal operating pressure;
- Maximum weight;
- Maximum amount of decay heat; and
- Identification and volumes of any coolants.

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§ 71.35 Package evaluation

- The application must include the following:
  - A demonstration that the package satisfies the standards specified in subparts E and F of this part;
  - For a fissile material package, the allowable number of packages that may be transported in the same vehicle in accordance with § 71.59; and
  - For a fissile material shipment, any proposed special controls and precautions for transport, loading, unloading, and handling and any proposed special controls in case of an accident or delay.

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Subpart E--Package Approval Standards (71.41 – 71.65)

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§ 71.41 Demonstration of compliance

- The effects on a package of the tests specified in § 71.71 ("Normal conditions of transport"), and the tests specified in § 71.73 ("Hypothetical accident conditions"), and § 71.61 ("Special requirements for Type B packages containing more than 105 A2"), must be evaluated by subjecting a specimen or scale model to a specific test, or by another method of demonstration acceptable to the Commission, as appropriate for the particular feature being considered.
- Taking into account the type of vehicle, the method of securing or attaching the package, and the controls to be exercised by the shipper, the Commission may permit the shipment to be evaluated together with the transporting vehicle.
- Environmental and test conditions different from those specified in §§ 71.71 and 71.73 may be approved by the Commission if the controls proposed to be exercised by the shipper are demonstrated to be adequate to provide equivalent safety of the shipment.
- Packages for which compliance with the other provisions of these regulations is impracticable shall not be transported except under special package authorization. Provided the applicant demonstrates that compliance with the other provisions of the regulations is impracticable and that the requisite standards of safety established by these regulations have been demonstrated through means alternative to the other provisions, a special package authorization may be approved for one-time shipments. The applicant shall demonstrate that the overall level of safety in transport for these shipments is at least equivalent to that which would be provided if all the applicable requirements had been met.

§ 71.43 General standards for all packages

- The smallest overall dimension of a package may not be less than 10 cm (4 in).
- The outside of a package must incorporate a feature, such as a seal, that is not readily breakable and that, while intact, would be evidence that the package has not been opened by unauthorized persons.
- Each package must include a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package.
- A package must be made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction among the packaging components, among package contents, or between the packaging components and the package contents, including possible reaction resulting from inleakage of water, to the maximum credible extent. Account must be taken of the behavior of materials under irradiation.
- A package valve or other device, the failure of which would allow radioactive contents to escape, must be protected against unauthorized operation and, except for a pressure relief device, must be provided with an enclosure to retain any leakage.
- A package must be designed, constructed, and prepared for shipment so that under the tests specified in § 71.71 ("Normal conditions of transport") there would be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging.
- A package must be designed, constructed, and prepared for transport so that in still air at 38°C (100°F) and in the shade, no accessible surface of a package would have a temperature exceeding 50°C (122°F) in a nonexclusive use shipment, or 85°C (185°F) in an exclusive use shipment.
- A package may not incorporate a feature intended to allow continuous venting during transport.

§ 71.45 Lifting and tie-down standards for all packages

- Any lifting attachment that is a structural part of a package must be designed with a minimum safety factor of three against yielding when used to lift the package in the intended manner, and it must be designed so that failure of any lifting device under excessive load would not impair the ability of the package to meet other requirements of this subpart. Any other structural part of the package that could be used to lift the package must be capable of being rendered inoperable for lifting the package during transport, or must be designed with strength equivalent to that required for lifting attachments.
- Tie-down devices:
  - If there is a system of tie-down devices that is a structural part of the package, the system must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, a static force applied to the center of gravity of the package having a vertical component of 2 times the weight of the package with its contents, a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package with its contents, and a horizontal component in the transverse direction of 5 times the weight of the package with its contents.
  - Any other structural part of the package that could be used to tie down the package must be capable of being rendered inoperable for tying down the package during transport, or must be designed with strength equivalent to that required for tie-down devices.
  - Each tie-down device that is a structural part of a package must be designed so that failure of the device under excessive load would not impair the ability of the package to meet other requirements of this part.

§ 71.47 External radiation standards for all packages

- Except as provided in paragraph (b) of this section, each package of radioactive materials offered for transportation must be designed and prepared for shipment so that under conditions normally incident to transportation the radiation level does not exceed 2 mSv/h (200 mrem/h) at any point on the external surface of the package, and the transport index does not exceed 10.
- A package that exceeds the radiation level limits specified in paragraph (a) of this section must be transported by exclusive use shipment only, and the radiation levels for such shipment must not exceed the following during transportation:
  - 2 mSv/h (200 mrem/h) on the external surface of the package, unless the following conditions are met, in which case the limit is 10 mSv/h (1000 mrem/h):
    - (i) The shipment is made in a closed transport vehicle;
    - (ii) The package is secured within the vehicle so that its position remains fixed during transportation; and
    - (iii) There are no loading or unloading operations between the beginning and end of the transportation;
  - 2 mSv/h (200 mrem/h) at any point on the outer surface of the vehicle, including the top and underside of the vehicle; or in the case of a flat-bed style vehicle, at any point on the vertical planes projected from the outer edges of the vehicle, on the upper surface of the load or enclosure, if used, and on the lower external surface of the vehicle; and
  - 0.1 mSv/h (10 mrem/h) at any point 2 meters (80 in) from the outer lateral surfaces of the vehicle (excluding the top and underside of the vehicle); or in the case of a flat-bed style vehicle, at any point 2 meters (6.6 feet) from the vertical planes projected by the outer edges of the vehicle (excluding the top and underside of the vehicle); and
  - 0.02 mSv/h (2 mrem/h) in any normally occupied space, except that this provision does not apply to private carriers, if exposed personnel under their control wear radiation dosimetry devices in conformance with 10 CFR 20.1502.

§ 71.47 External radiation standards for all packages (cont.)

- For shipments made under the provisions of paragraph (b) of this section, the shipper shall provide specific written instructions to the carrier for maintenance of the exclusive use shipment controls. The instructions must be included with the shipping paper information.

- The written instructions required for exclusive use shipments must be sufficient so that, when followed, they will cause the carrier to avoid actions that will unnecessarily delay delivery or unnecessarily result in increased radiation levels or radiation exposures to transport workers or members of the general public.

§ 71.51 Additional requirements for Type B packages

- A Type B package, in addition to satisfying the requirements of §§ 71.41 through 71.47, must be designed, constructed, and prepared for shipment so that under the tests specified in:
  - Section 71.71 ("Normal conditions of transport"), there would be no loss or dispersal of radioactive contents--as demonstrated to a sensitivity of 10-6 A_2 per hour, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging; and
  - Section 71.73 ("Hypothetical accident conditions"), there would be no escape of krypton-85 exceeding 10 A_2 in 1 week, no escape of other radioactive material exceeding a total amount A_2 in 1 week, and no external radiation dose rate exceeding 10 mSv/h (1 rem/h) at 1 m (40 in) from the external surface of the package.
- Where mixtures of different radionuclides are present, the provisions of appendix A, paragraph IV of this part shall apply, except that for Krypton-85, an effective A_2 value equal to 10 A_2 may be used.
- Compliance with the permitted activity release limits of paragraph (a) of this section may not depend on filters or on a mechanical cooling system.
- For packages which contain radioactive contents with activity greater than 10^5 A_2, the requirements of § 71.61 must be met.

§ 71.55 General requirements for fissile material packages

- A package used for the shipment of fissile material must be designed and constructed in accordance with §§ 71.41 through 71.47. When required by the total amount of radioactive material, a package used for the shipment of fissile material must also be designed and constructed in accordance with § 71.51.
- Except as provided in paragraph (c) or (g) of this section, a package used for the shipment of fissile material must be so designed and constructed and its contents so limited that it would be subcritical if water were to leak into the containment system, or liquid contents were to leak out of the containment system so that, under the following conditions, maximum reactivity of the fissile material would be attained:
  - The most reactive credible configuration consistent with the chemical and physical form of the material;
  - Moderation by water to the most reactive credible extent; and
  - Close full reflection of the containment system by water on all sides, or such greater reflection of the containment system as may additionally be provided by the surrounding material of the packaging.
- The Commission may approve exceptions to the requirements of paragraph (b) of this section if the package incorporates special design features that ensure that no single packaging error would permit leakage, and if appropriate measures are taken before each shipment to ensure that the containment system does not leak.

§ 71.55 General requirements for fissile material packages (cont.)

- A package used for the shipment of fissile material must be so designed and constructed and its contents so limited that under the tests specified in § 71.71 ("Normal conditions of transport") --
  - The contents would be subcritical;
  - The geometric form of the package contents would not be substantially altered;
  - There would be no leakage of water into the containment system unless, in the evaluation of undamaged packages under § 71.59(a)(1), it has been assumed that moderation is present to such an extent as to cause maximum reactivity consistent with the chemical and physical form of the material; and
  - There will be no substantial reduction in the effectiveness of the packaging, including:
    - No more than 5 percent reduction in the total effective volume of the packaging on which nuclear safety is assessed;
    - No more than 5 percent reduction in the effective spacing between the fissile contents and the outer surface of the packaging; and
    - No occurrence of an aperture in the outer surface of the packaging large enough to permit the entry of a 10 cm (4 in) cube.

§ 71.55 General requirements for fissile material packages (cont.)

- A package used for the shipment of fissile material must be so designed and constructed and its contents so limited that under the tests specified in § 71.73 ("Hypothetical accident conditions"), the package would be subcritical. For this determination, it must be assumed that:
  - The fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents;
  - Water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents; and
  - There is full reflection by water on all sides, as close as is consistent with the damaged condition of the package.

§ 71.55 General requirements for fissile material packages (cont.)

For fissile material package designs to be transported by air:

- The package must be designed and constructed, and its contents limited so that it would be subcritical, assuming reflection by 20 cm (7.9 in) of water but no water inleakage, when subjected to sequential application of:
  - The free drop test in § 71.73(c)(1);
  - The crush test in § 71.73(c)(2);
  - A puncture test, for packages of 250 kg or more, consisting of a free drop of the specimen through a distance of 3 m (120 in) in a position for which maximum damage is expected at the conclusion of the test sequence, onto the upper end of a solid, vertical, cylindrical, mild steel probe mounted on an essentially unyielding, horizontal surface. The probe must be 20 cm (7.9 in) in diameter, with the striking end forming the frustum of a right circular cone with the dimensions of 30 cm height, 2.5 cm top diameter, and a top edge rounded to a radius of not more than 6 mm (0.25 in). For packages less than 250 kg, the puncture test must be the same, except that a 250 kg probe must be dropped onto the specimen which must be placed on the surface; and
  - The thermal test in § 71.73(c)(4), except that the duration of the test must be 60 minutes.
- The package must be designed and constructed, and its contents limited, so that it would be subcritical, assuming reflection by 20 cm (7.9 in) of water but no water inleakage, when subjected to an impact on an unyielding surface at a velocity of 90 m/s normal to the surface, at such orientation so as to result in maximum damage. A separate, undamaged specimen can be used for this evaluation.
- Allowance may not be made for the special design features in paragraph (c) of this section, unless water leakage into or out of void spaces is prevented following application of the tests in paragraphs (f)(1) and (f)(2) of this section, and subsequent application of the immersion test in § 71.73(c)(5).

§ 71.55 General requirements for fissile material packages (cont.)

- Packages containing uranium hexafluoride only are excepted from the requirements of paragraph (b) of this section provided that:
  - Following the tests specified in § 71.73 ("Hypothetical accident conditions"), there is no physical contact between the valve body and any other component of the packaging, other than at its original point of attachment, and the valve remains leak tight;
  - There is an adequate quality control in the manufacture, maintenance, and repair of packagings;
  - Each package is tested to demonstrate closure before each shipment; and
  - The uranium is enriched to not more than 5 weight percent uranium-235.

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§ 71.61 Special requirements for Type B packages containing more than 10^5A_2

- A Type B package containing more than 10^5A_2 must be designed so that its undamaged containment system can withstand an external water pressure of 2 MPa (290 psi) for a period of not less than 1 hour without collapse, buckling, or inleakage of water.

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Subpart F--Package, Special Form, and LSA-III Tests (71.71 – 71.77)

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§ 71.71 Normal conditions of transport

- ***Evaluation.*** **Evaluation of each package design under normal conditions of transport must include a determination of the effect on that design of the conditions and tests specified in this section. Separate specimens may be used for the free drop test, the compression test, and the penetration test, if each specimen is subjected to the water spray test before being subjected to any of the other tests.**
- ***Initial conditions.*** **With respect to the initial conditions for the tests in this section, the demonstration of compliance with the requirements of this part must be based on the ambient temperature preceding and following the tests remaining constant at that value between -29°C (-20°F) and +38°C (+100°F) which is most unfavorable for the feature under consideration. The initial internal pressure within the containment system must be considered to be the maximum normal operating pressure, unless a lower internal pressure consistent with the ambient temperature considered to precede and follow the tests is more unfavorable.**

§ 71.71 Normal conditions of transport (cont.)

- ***Conditions and tests*.**
  - ***Heat.*** **An ambient temperature of 38°C (100°F) in still air, and insolation according to the following table:**

INSOLATION DATA

Form and location of surface	Total insolation for a 12-hour period (g cal/cm^2
Flat surfaces transported horizontally:	
Base	None
Other surfaces	800
Flat surfaces not transported horizontally	200
Curved surfaces	400

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§ 71.71 Normal conditions of transport (cont.)

- ***Cold.*** **An ambient temperature of -40°C (-40°F) in still air and shade.**
- ***Reduced external pressure.*** **An external pressure of 25 kPa (3.5 lbf/in2) absolute.**
- ***Increased external pressure.*** **An external pressure of 140 kPa (20 lbf/in2) absolute.**
- ***Vibration.*** **Vibration normally incident to transport.**
- ***Water spray.*** **A water spray that simulates exposure to rainfall of approximately 5 cm/h (2 in/h) for at least 1 hour.**

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§ 71.71 Normal conditions of transport (cont.)

- ***Free drop*. Between 1.5 and 2.5 hours after the conclusion of the water spray test, a free drop through the distance specified below onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.**

CRITERIA FOR FREE DROP TEST (WEIGHT/DISTANCE)

Package weight		Free drop distance	
Kilograms	(Pounds)	Meters	(Feet)
Less than 5,000	(Less than 11,000)	1.2	(4)
5,000 to 10,000	(11,000 to 22,000)	0.9	(3)
10,000 to 15,000 ...	(22,000 to 33,100)	0.6	(2)
More than 15,000 ..	(More than 33,100)	0.3	(1)

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§ 71.71 Normal conditions of transport (cont.)

- ***Corner drop.*** **A free drop onto each corner of the package in succession, or in the case of a cylindrical package onto each quarter of each rim, from a height of 0.3 m (1 ft) onto a flat, essentially unyielding, horizontal surface. This test applies only to fiberboard, wood, or fissile material rectangular packages not exceeding 50 kg (110 lbs) and fiberboard, wood, or fissile material cylindrical packages not exceeding 100 kg (220 lbs).**
- ***Compression.*** **For packages weighing up to 5000 kg (11,000 lbs), the package must be subjected, for a period of 24 hours, to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The compressive load must be the greater of the following:**
  - **The equivalent of 5 times the weight of the package; or**
  - **The equivalent of 13 kPa (2 lbf/in^2) multiplied by the vertically projected area of the package.**
- ***Penetration.*** **Impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1.25 in) diameter and 6 kg (13 lbs) mass, dropped from a height of 1 m (40 in) onto the exposed surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the package surface.**

§ 71.73 Hypothetical accident conditions

- ***Test procedures.*** **Evaluation for hypothetical accident conditions is to be based on sequential application of the tests specified in this section, in the order indicated, to determine their cumulative effect on a package or array of packages. An undamaged specimen may be used for the water immersion tests specified in paragraph (c)(6) of this section.**
- ***Test conditions.*** **With respect to the initial conditions for the tests, except for the water immersion tests, to demonstrate compliance with the requirements of this part during testing, the ambient air temperature before and after the tests must remain constant at that value between -29°C (-20°F) and +38°C (+100°F) which is most unfavorable for the feature under consideration. The initial internal pressure within the containment system must be the maximum normal operating pressure, unless a lower internal pressure, consistent with the ambient temperature assumed to precede and follow the tests, is more unfavorable.**

§ 71.73 Hypothetical accident conditions (cont.)

- ***Tests.*** **Tests for hypothetical accident conditions must be conducted as follows:**
  - ***Free Drop.*** **A free drop of the specimen through a distance of 9 m (30 ft) onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.**
  - ***Crush.*** **Subjection of the specimen to a dynamic crush test by positioning the specimen on a flat, essentially unyielding horizontal surface so as to suffer maximum damage by the drop of a 500-kg (1100-lb) mass from 9 m (30 ft) onto the specimen. The mass must consist of a solid mild steel plate 1 m (40 in) by 1 m (40 in) and must fall in a horizontal attitude. The crush test is required only when the specimen has a mass not greater than 500 kg (1100 lb), an overall density not greater than 1000 kg/m3 (62.4 lb/ft3) based on external dimension, and radioactive contents greater than 1000 A2 not as special form radioactive material. For packages containing fissile material, the radioactive contents greater than 1000 A2 criterion does not apply.**

§ 71.73 Hypothetical accident conditions (cont.)

- ***Puncture.*** **A free drop of the specimen through a distance of 1 m (40 in) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 15 cm (6 in) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (0.25 in), and of a length as to cause maximum damage to the package, but not less than 20 cm (8 in) long. The long axis of the bar must be vertical.**

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§ 71.73 Hypothetical accident conditions (cont.)

- ***Thermal.*** **Exposure of the specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent, and in sufficiently quiescent ambient conditions, to provide an average emissivity coefficient of at least 0.9, with an average flame temperature of at least 800°C (1475°F) for a period of 30 minutes, or any other thermal test that provides the equivalent total heat input to the package and which provides a time averaged environmental temperature of 800°C. The fuel source must extend horizontally at least 1 m (40 in), but may not extend more than 3 m (10 ft), beyond any external surface of the specimen, and the specimen must be positioned 1 m (40 in) above the surface of the fuel source. For purposes of calculation, the surface absorptivity coefficient must be either that value which the package may be expected to possess if exposed to the fire specified or 0.8, whichever is greater; and the convective coefficient must be that value which may be demonstrated to exist if the package were exposed to the fire specified. Artificial cooling may not be applied after cessation of external heat input, and any combustion of materials of construction, must be allowed to proceed until it terminates naturally.**

§ 71.73 Hypothetical accident conditions (cont.)

- ***Immersion--fissile material.*** **For fissile material subject to § 71.55, in those cases where water inleakage has not been assumed for criticality analysis, immersion under a head of water of at least 0.9 m (3 ft) in the attitude for which maximum leakage is expected.**
- ***Immersion--all packages.*** **A separate, undamaged specimen must be subjected to water pressure equivalent to immersion under a head of water of at least 15 m (50 ft). For test purposes, an external pressure of water of 150 kPa (21.7 lbf/in2) gauge is considered to meet these conditions.**

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§ 71.75 Qualification of special form radioactive material

- Special form radioactive materials must meet the test requirements of paragraph (b) of this section. Each solid radioactive material or capsule specimen to be tested must be manufactured or fabricated so that it is representative of the actual solid material or capsule that will be transported, with the proposed radioactive content duplicated as closely as practicable. Any differences between the material to be transported and the test material, such as the use of non-radioactive contents, must be taken into account in determining whether the test requirements have been met. In addition:
  - A different specimen may be used for each of the tests;
  - The specimen may not break or shatter when subjected to the impact, percussion, or bending tests;
  - The specimen may not melt or disperse when subjected to the heat test;
  - After each test, leaktightness or indispersibility of the specimen must be determined by a method no less sensitive than the leaching assessment procedure prescribed in paragraph (c) of this section. For a capsule resistant to corrosion by water, and which has an internal void volume greater than 0.1 milliliter, an alternative to the leaching assessment is a demonstration of leaktightness of x10-4 torr-liter/s (1.3xx10-4 atm-cm3/s) based on air at 25°C (77°F) and one atmosphere differential pressure for solid radioactive content, or x10-6 torr-liter/s (1.30xx10-6 atm-cm3/s) for liquid or gaseous radioactive content; and
  - A specimen that comprises or simulates radioactive material contained in a sealed capsule need not be subjected to the leaktightness procedure specified in this section, provided it is alternatively subjected to any of the tests prescribed in ISO/TR4826-1979(E), "Sealed radioactive sources leak test methods" which is available from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

§ 71.75 Qualification of special form radioactive material (cont.)

Test methods:

- ***Impact Test.*** **The specimen must fall onto the target from a height of 9 m (30 ft) or greater in the orientation expected to result in maximum damage. The target must be a flat, horizontal surface of such mass and rigidity that any increase in its resistance to displacement or deformation, on impact by the specimen, would not significantly increase the damage to the specimen.**
- ***Percussion Test.***
  - **The specimen must be placed on a sheet of lead that is supported by a smooth solid surface, and struck by the flat face of a steel billet so as to produce an impact equivalent to that resulting from a free drop of 1.4 kg (3 lbs) through 1 m (40 in);**
  - **The flat face of the billet must be 25 millimeters (mm) (1 inch) in diameter with the edges rounded off to a radius of 3 mm±0.3 mm(.12 in±0.012 in);**
  - **The lead must be hardness number 3.5 to 4.5 on the Vickers scale and thickness 25 mm (1 in) or greater, and must cover an area greater than that covered by the specimen;**
  - **A fresh surface of lead must be used for each impact; and**
  - **The billet must strike the specimen so as to cause maximum damage.**
- ***Bending test.***
  - **This test applies only to long, slender sources with a length of 10 cm (4 inches) or greater and a length to width ratio of 10 or greater;**
  - **The specimen must be rigidly clamped in a horizontal position so that one half of its length protrudes from the face of the clamp;**
  - **The orientation of the specimen must be such that the specimen will suffer maximum damage when its free end is struck by the flat face of a steel billet;**
  - **The billet must strike the specimen so as to produce an impact equivalent to that resulting from a free vertical drop of 1.4 kg (3 lbs) through 1 m (40 in); and**
  - **The flat face of the billet must be 25 mm (1 inch) in diameter with the edges rounded off to a radius of 3 mm±0.3 mm (.12 in±0.012 in).**
- ***Heat test.*** **The specimen must be heated in air to a temperature of not less than 800°C (1475°F), held at that temperature for a period of 10 minutes, and then allowed to cool.**

§ 71.75 Qualification of special form radioactive material (cont.)

Leaching assessment methods.

- **For indispersible solid material --**
  - **The specimen must be immersed for 7 days in water at ambient temperature. The water must have a pH of 6-8 and a maximum conductivity of 10 micromho per centimeter at 20° (68°F);**
  - **The water with specimen must then be heated to a temperature of 50°C±5°C (122°F±9°F) and maintained at this temperature for 4 hours.**
  - **The activity of the water must then be determined;**
  - **The specimen must then be stored for at least 7 days in still air of relative humidity not less than 90 percent at 30°C (86°F);**
  - **The specimen must then be immersed in water under the same conditions as in paragraph (c)(1)(i) of this section, and the water with specimen must be heated to 50°C±5°C (122°F±9°F) and maintained at that temperature for 4 hours;**
  - **The activity of the water must then be determined. The sum of the activities determined here and in paragraph (c)(1)(iii) of this section must not exceed 2 kilobecquerels (kBq) (0.05 microcurie (μCi)).**
- **For encapsulated material --**
  - **The specimen must be immersed in water at ambient temperature. The water must have a pH of 6-8 and a maximum conductivity of 10 micromho per centimeter;**
  - **The water and specimen must be heated to a temperature of 50°C±5°C (122°F±9°F) and maintained at this temperature for 4 hours;**
  - **The activity of the water must then be determined;**
  - **The specimen must then be stored for at least 7 days in still air at a temperature of 30°C (86°F) or greater;**
  - **The process in paragraph (c)(2)(i), (ii), and (iii) of this section must be repeated; and**
  - **The activity of the water must then be determined. The sum of the activities determined here and in paragraph (c)(2)(iii) of this section must not exceed 2 kilobecquerels (kBq) (0.05 microcurie (Ci)).**

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§ 71.75 Qualification of special form radioactive material (cont.)

- A specimen that comprises or simulates radioactive material contained in a sealed capsule need not be subjected to --
  - The impact test and the percussion test of this section, provided that the specimen is alternatively subjected to the Class 4 impact test prescribed in ISO 2919-1980(e), "Sealed Radioactive Sources Classification" (see § 71.75(a)(5) for statement of availability); and
  - The heat test of this section, provided the specimen is alternatively subjected to the Class 6 temperature test specified in the International Organization for Standardization document ISO 2919-1980(e), "Sealed Radioactive Sources Classification."

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§ 71.77 Qualification of LSA-III Material

- LSA-III material must meet the test requirements of paragraph (b) of this section. Any differences between the specimen to be tested and the material to be transported must be taken into account in determining whether the test requirements have been met.
- *Leaching Test*.
  - The specimen, representing no less than the entire contents of the package, must be immersed for 7 days in water at ambient temperature;
  - The volume of water to be used in the test must be sufficient to ensure that at the end of the test period the free volume of the unabsorbed and unreacted water remaining will be at least 10% of the volume of the specimen itself;
  - The water must have an initial pH of 6-8 and a maximum conductivity 10 micromho/cm at 20°C (68°F); and
  - The total activity of the free volume of water must be measured following the 7 day immersion test and must not exceed 0.1 A_2.

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Subpart G--Operating Controls and Procedures (71.81 – 100)

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Subpart H--Quality Assurance (71.101 – 71.137)

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Appendix A to Part 71-- Determination of A_1 and A_2

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Determination of A_1 and A_2

- I. Values of A_1 and A_2 for individual radionuclides, which are the bases for many activity limits elsewhere in these regulations, are given in Table A-1. The curie (Ci) values specified are obtained by converting from the Terabecquerel (TBq) value. The Terabecquerel values are the regulatory standard. The curie values are for information only and are not intended to be the regulatory standard. Where values of A_1 and A_2 are unlimited, it is for radiation control purposes only. For nuclear criticality safety, some materials are subject to controls placed on fissile material.

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Determination of A_1 and A_2 (cont.)

- **Table A-1:**

TABLE A–1—A_1 AND A_2 VALUES FOR RADIONUCLIDES

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)[b]	A_2 (TBq)	A_2 (Ci)[b]	Specific activity (TBq/g)	Specific activity (Ci/g)
Ac-225 (a)	Actinium (89)	8.0×10^{-1}	2.2×10^{1}	6.0×10^{-3}	1.6×10^{-1}	2.1×10^{3}	5.8×10^{4}
Ac-227 (a)		9.0×10^{-1}	2.4×10^{1}	9.0×10^{-5}	2.4×10^{-3}	2.7	7.2×10^{1}
Ac-228		6.0×10^{-1}	1.6×10^{1}	5.0×10^{-1}	1.4×10^{1}	8.4×10^{4}	2.2×10^{6}
Ag-105	Silver (47)	2.0	5.4×10^{1}	2.0	5.4×10^{1}	1.1×10^{3}	3.0×10^{4}

- **Table A-2:**

TABLE A–2—EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Ac-225	Actinium (89)	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
Ac-227		1.0×10^{-1}	2.7×10^{-12}	1.0×10^{3}	2.7×10^{-8}
Ac-228		1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Ag-105	Silver (47)	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}

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Determination of A_1 and A_2 (cont.)

- II. a. For individual radionuclides whose identities are known, but which are not listed in Table A-1, the A_1 and A_2 values contained in Table A-3 may be used. Otherwise, the licensee shall obtain prior Commission approval of the A_1 and A_2 values for radionuclides not listed in Table A-1, before shipping the material.
- b. For individual radionuclides whose identities are known, but which are not listed in Table A-2, the exempt material activity concentration and exempt consignment activity values contained in Table A-3 may be used. Otherwise, the licensee shall obtain prior Commission approval of the exempt material activity concentration and exempt consignment activity values for radionuclides not listed in Table A-2, before shipping the material.
- c. The licensee shall submit requests for prior approval, described under paragraphs II(a) and II(b) of this Appendix, to the Commission, in accordance with § 71.1 of this part.

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Determination of A_1 and A_2 (cont.)

- III. In the calculations of A_1 and A_2 for a radionuclide not in Table A-1, a single radioactive decay chain, in which radionuclides are present in their naturally occurring proportions, and in which no daughter radionuclide has a half-life either longer than 10 days, or longer than that of the parent radionuclide, shall be considered as a single radionuclide, and the activity to be taken into account, and the A_1 or A_2 value to be applied, shall be those corresponding to the parent radionuclide of that chain. In the case of radioactive decay chains in which any daughter radionuclide has a half-life either longer than 10 days, or greater than that of the parent radionuclide, the parent and those daughter radionuclides shall be considered as mixtures of different radionuclides.

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Determination of A_1 and A_2 (cont.)

- **IV. For mixtures of radionuclides whose identities and respective activities are known, the following conditions apply:**
  - **For special form radioactive material, the maximum quantity transported in a Type A package is as follows:**

$$\sum_i \frac{B(i)}{A_1(i)} \leq 1$$

where B(i) is the activity of radionuclide i, and A1(i) is the A_1 value for radionuclide i.

  - **For normal form radioactive material, the maximum quantity transported in a Type A package is as follows:**

$$\sum B(i)/A_2(i) \leq 1$$

where B(i) is the activity of radionuclide i, and $A_2(i)$ is the A_2 value for radionuclide i.

- **Alternatively, the A1 value for mixtures of special form material may be determined as follows:**

$$A_1 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_1(i)}}$$

where f(i) is the fraction of activity for radionuclide i in the mixture, and $A_1(i)$ is the appropriate A_1 value for radionuclide i.

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Determination of A_1 and A_2 (cont.)

- **Alternatively, the A_2 value for mixtures of normal form material may be determined as follows:**

$$A_2 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_2(i)}}$$

where f(i) is the fraction of activity for radionuclide i in the mixture, and $A_2(i)$ is the appropriate A_2 value for radionuclide i.

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Determination of A_1 and A_2 (cont.)

- **The exempt activity concentration for mixtures of nuclides may be determined as follows:**

$$\text{Exempt activity concentration for mixture} = \frac{1}{\sum_i \frac{f(i)}{[A](i)}}$$

where f(i) is the fraction of activity concentration of radionuclide i in the mixture, and [A] is the activity concentration for exempt material containing radionuclide i.

- **The activity limit for an exempt consignment for mixtures of radionuclides may be determined as follows:**

$$\text{Exempt consignment activity limit for mixture} = \frac{1}{\sum_i \frac{f(i)}{A(i)}}$$

where f(i) is the fraction of activity of radionuclide i in the mixture, and A is the activity limit for exempt consignments for radionuclide i.

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Determination of A_1 and A_2 (cont.)

- When the identity of each radionuclide is known, but the individual activities of some of the radionuclides are not known, the radionuclides may be grouped, and the lowest A_1 or A_2 value, as appropriate, for the radionuclides in each group may be used in applying the formulas in paragraph IV. Groups may be based on the total alpha activity and the total beta/gamma activity when these are known, using the lowest A_1 or A_2 values for the alpha emitters and beta/gamma emitters.

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