This publication is no longer valid
Please see http://www-ns.iaea.org/standards/
REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIALS
The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ARGENTINA
AUSTRALIA
AUSTRIA
BELGIUM
BRAZIL
BULGARIA
BURMA
BYELORUSSIAN SOVIET SOCIALIST REPUBLIC
CAMBODIA
CANADA
CEYLON
CHILE
CHINA
COLOMBIA
CUBA
CZECHOSLOVAK SOCIALIST REPUBLIC
DENMARK
DOMINICAN REPUBLIC
ECUADOR
EL SALVADOR
ETHIOPIA
FINLAND
FRANCE
FEDERAL REPUBLIC OF GERMANY
GHANA
GREECE
GUATEMALA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAQ
ISRAEL
ITALY
JAPAN
REPUBLIC OF KOREA
LUXEMBOURG
MEXICO
MONACO
MOROCCO
NETHERLANDS
NEW ZEALAND
NICARAGUA
NORWAY
PAKISTAN
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
ROMANIA
SENEGAL
SPAIN
SUDAN
SWEDEN
SWITZERLAND
THAILAND
TUNISIA
TURKEY
UKRAINIANSOVET SOCIALIST REPUBLIC
UNION OF SOUTH AFRICA
UNION OF SOVIET SOCIALIST REPUBLICS
UNITED ARAB REPUBLIC
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED STATES OF AMERICA
VENEZUELA
VIET-NAM
YUGOSLAVIA

The Agency’s Statute was approved on 26 October 1956 at an international conference held at United Nations headquarters, New York, and the Agency came into being when the Statute entered into force on 29 July 1957. The first session of the General Conference was held in Vienna, Austria, the permanent seat of the Agency, in October, 1957.

The main objective of the Agency is “to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world”.

© I A E A, 1961

Permission to reproduce or translate the information contained in this publication may be obtained by writing to the International Atomic Energy Agency, Kaerntenerring 11, Vienna I.

Printed in Austria by Paul Gerin, Vienna

May 1961
REGULATIONS
FOR THE SAFE TRANSPORT
OF RADIOACTIVE MATERIALS

INTERNATIONAL ATOMIC ENERGY AGENCY
Kaerntnerring, Vienna I, Austria
1961
THESE REGULATIONS ARE ALSO PUBLISHED
IN FRENCH, RUSSIAN AND SPANISH

REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIALS, IAEA, VIENNA, 1961

STI/PUB/40
The transport of increasing amounts of radioactive materials within many countries and across international frontiers poses technical problems because of the hazards associated with the movement of these materials.

The expanding use of radioactive materials for peaceful purposes in most parts of the world demands that the international transport of these materials should benefit from the adoption, on as wide a scale as possible, of uniform safety rules.

In order that the procedures to be complied with by the users should not be too complex, the basic requirements of such rules must be applicable to a considerable extent to air, water and land transport alike, whatever the method of carriage.

In this new volume of the Safety Series, the International Atomic Energy Agency aims to propose safety regulations which can be applied to the national and international transport of radioactive materials by all means of transport.

These Regulations have been prepared by the International Atomic Energy Agency, within the framework of its statutory functions, in accordance with recommendations made by its Preparatory Commission and by the Economic and Social Council* of the United Nations.

In presenting these Regulations to the users, I am confident that they are based on a considered assessment of the problem and offer a practical and adaptable means of dealing with it.

May 1961

Director General

* On 17 July 1959, by Resolution 724 C (XXVIII), the Council expressed the desire “that the Agency be entrusted with the drafting of recommendations on the transport of radioactive substances ... within the ... general principles ... of the Committee of Experts on the Transport of Dangerous Goods ... and in consultation with the United Nations and the Specialized Agencies concerned”.

This publication is no longer valid
Please see http://www-ns.iaea.org/standards/
A study of appropriate safety provisions for the carriage of radioactive materials by air in "wing-tip" containers is being carried out by the Agency, and the results will be published in due course. In the meantime, such carriage should not be considered as prohibited under the present Regulations, but should be arranged with the appropriate authority.

The International Atomic Energy Agency wishes to indicate that the colour (yellow) for the labels of packages referred to in sub-section 7.2. and elsewhere in these Regulations is provisional and that the matter has been referred by the Agency to the United Nations Committee of Experts for Further Work on the Transport of Dangerous Goods for further consideration.

ABBREVIATIONS EMPLOYED IN THESE REGULATIONS

The following international standard abbreviations for units are employed in these Regulations; see also those contained in sub-section 1.2. For a list of the symbols of the elements, see Table IV in Annex I of these Regulations.

\[
\begin{align*}
\text{centimeter} & \quad - \quad \text{cm} \\
\text{curie} & \quad - \quad \text{c} \\
\text{foot} & \quad - \quad \text{ft} \\
\text{gram} & \quad - \quad \text{g} \\
\text{hour} & \quad - \quad \text{h} \\
\text{inch} & \quad - \quad \text{in} \\
\text{kilogram} & \quad - \quad \text{kg} \\
\text{liter} & \quad - \quad \text{l} \\
\text{meter} & \quad - \quad \text{m} \\
\text{microcurie} & \quad - \quad \mu\text{c} \\
\text{millicurie} & \quad - \quad \text{mc} \\
\text{milliroentgen} & \quad - \quad \text{mr} \\
\text{roentgen} & \quad - \quad \text{r} \\
\text{second} & \quad - \quad \text{s} \\
\text{year} & \quad - \quad \text{yr}
\end{align*}
\]
INTRODUCTION ....................................................................................... 9
LIST OF PANEL PARTICIPANTS ..................................................... 10
1. DEFINITIONS AND UNITS ................................................... 13
2. SCOPE OF THE REGULATIONS ............................................. 14
3. GENERAL PRINCIPLES ....................................................... 15
4. CONTROL OF EXPOSURE OF PERSONS TO RADIATION . . 15
5. GENERAL PACKAGING REQUIREMENTS ................................ 16
6. LIMITATION OF QUANTITIES OF RADIOACTIVE MATERIALS IN A PACKAGE ............................................................. 19
6.1. Classification of radioisotopes ................................................ 19
6.2. Maximum radioactivity in a package ...................................... 19
7. LIMITATION OF EXTERNAL RADIATION DOSE RATE . . 22
7.1. White category ............................................................................................22
7.2. Yellow category ............................................................................................23
7.3. Measuring instruments ............................................................................23
8. LABELLING AND MARKING ...........................................................24
8.1. Labelling and marking of packages and containers........................... 24
8.2. Labelling or otherwise marking of vehicles ................................... 26
9. TRANSPORT DOCUMENTS ...........................................................27
9.1. Information required ...........................................................................27
9.2. Certification by consignor ............................................................................27
9.3. Language(s) to be used in these documents .................................28
10. LOADING AND STORAGE ............................................................28
10.1. Secure stowing .............................................................................................28
10.2. Limitation of the number of packages ..................................................28
10.3. Prohibition on mixed loading and storage ............................................29
10.4. Protection of persons .............................................................. 29
11. RADIOACTIVE CONTAMINATION OF THE CONVEYANCES AND OF THE OUTER SURFACES OF PACKAGES .............................................................................. 29
12. CUSTOMS ..........................................................................................30
13. EXEMPTIONS FROM THE REGULATIONS CONTAINED IN SECTIONS 5 TO 12 .............................................................................. 30
13.1. Conditions of exemption of Group 1 materials ................................... 30
13.2. Conditions of exemption of Group II and Group III materials •  . 30
13.3. Rules for instruments with radioactive materials as components . . 31
13.4. Empty packages ............................................................................................31
14. TRANSPORT OF RADIOACTIVE MATERIALS OF LOW SPECIFIC ACTIVITY .............................................................................. 32
15. FISSILE MATERIALS .............................................................................. 35
15.1. Scope ............................................................................................................... 35
15.2. Classes of shipments of fissile materials ............................................. 35
15.2.1. Class I — Shipments in packages such that each package is safe from neutron interaction in any arrangement ................. 35
15.2.2. Class II — Shipments in packages which, because of limited numbers and limits on contents, are nuclearly safe in any arrangement . 36
15.2.3. Class III — Shipments under special arrangements ................. 36
15.3. General requirements for the carriage of fissile materials (including unirradiated and irradiated fuel) ........................................... 37
15.3.1. Type of packaging and criticality conditions ........................... 37
In preparing the Regulations set forth here, the International Atomic Energy Agency has taken into account the detailed national and international regulations for transport of radioactive materials that have been in existence for many years and have supplied effective solutions to a number of the problems involved. The work has been undertaken with a view to providing a synthesis of those regulations, whilst introducing amendments suggested by more recent developments in a field where so much experience is being gained very quickly.

The Agency was aided in its task by the work of two panels convened to study the problem. These were the Panel on the Transport of Radioisotopes and Radioactive Ores and Residues of Low Specific Activity and the panel on Transport of Large Radioactive Sources and Fissile Materials. These two panels met for the first time at the Agency’s Headquarters in Vienna 2—9 April and 13—17 July 1959 respectively. A list of participants follows below.

As a result of these meetings, draft regulations and complementary reports were drawn up and circulated for comment to all Member States of the Agency and to the international organizations concerned. Comments received were considered in a second series of meetings of the two panels, held 1—6 February and 8—13 February 1960 respectively. The final outcome of the panels' work is contained in the present document.

The draft regulations were unanimously approved by the Board of Governors in September 1960, and the fourth regular session of the General Conference of the Agency in the same month adopted, without a dissenting voice, a resolution welcoming the establishment of these Regulations.

They will now be applied to the Agency’s operations, and in appropriate cases to operations assisted by the Agency; and they have been recommended to Member States and to the international organizations concerned as a basis for national and international transport regulations. Member States of the Agency and international organizations concerned have been asked to indicate the extent to which the Regulations are being applied by them, and any difficulties they may have experienced in so doing, so that this information may be taken into account when the Regulations are reviewed, beginning in 1962 and every two years thereafter.

In connection with the Regulations, further scientific information and practical guidance relating to certain aspects of the problem of the transport of radioactive materials will be published in separate volumes of this Safety Series, beginning with No. 7.
PANEL ON THE TRANSPORT OF RADIOISOTOPES AND RADIOACTIVE ORES AND RESIDUES OF LOW SPECIFIC ACTIVITY

List of participants at the meetings held at the International Atomic Energy Agency Headquarters, Vienna, 2—9 April 1959 and 1—6 February 1960:

Chairman:
Mr. G. E. André
Union Minière du Haut-Katanga
Belgium

Members:
Dr. A. A. M. Ahmed (1st session)
Atomic Energy Commission
Pakistan

Dr. A. I. Hashmi (2nd session)
Atomic Energy Commission
Pakistan

Dr. G. Calcagno
Central Office of International Railway Transport

Mr. V. E. Haninger
Interstate Commerce Commission
United States of America

Mr. P. A. Lecomte
International Air Transport Association

Prof. E. Martin
Bundesanstalt für Materialprüfung
Federal Republic of Germany

Dr. A. Moreno y Moreno
Universidad Nacional Autónoma de México

Dr. W. Patlikowski
Institute for Railway Progress
Poland

Mr. A. H. K. Slater, accompanied by Mr. A. Fairbairn
United Kingdom Atomic Energy Authority
United Kingdom

Representatives of Specialized Agencies of the United Nations and other Inter-governmental Organizations:

Mr. A. Dollinger
Permanent United Nations Delegate to the International Atomic Energy Agency

Mr. J. Lareau (1st session)
Mr. E. Hellen (2nd session)
International Labour Office

Mr. J. A. Newton (1st session)
International Civil Aviation Organization

Mr. O. Pendar (1st session)
Mr. A. W. Clarke (2nd session)
United Nations Secretariat

Dr. P. Taillard
World Health Organization

Mr. A. Boënnc (2nd session)
Universal Postal Union
PANEL ON THE TRANSPORT OF LARGE
Radioactive Sources and Fissile Materials

List of participants at the meetings held at the International Atomic Energy Agency Headquarters, Vienna, 13—17 July 1959 and 8—13 February 1960:

**Chairman:**
Mr. Homi N. Sethna
Atomic Energy Establishment
India

**Members:**
Dr. J. Beranek
Atomic Energy Commission
Czechoslovakia

Dr. G. Calcagno
Central Office of International Railway Transport
France

Mr. P. Candès, accompanied by Mr. J. Lalère and Mr. H. Capet (2nd session)
Centre d'Etudes Nucléaires de Saclay
France

Mr. K. van Es, accompanied by Mr. G. A. Scassellati (2nd session)
International Road Transport Union

Mr. A. Fairbairn, accompanied by Mr. A. H. K. Slater
UK Atomic Energy Authority
United Kingdom

Mr. A. Jönsson
Swedish State Railways
Sweden

Mr. P. N. Krishnamoorthy
Atomic Energy Establishment
India

Mr. P. A. Lecomte (2nd session)
International Air Transport Association

Mr. L. R. Rogers
Atomic Energy Commission
United States of America
accompanied by Mr. V. E. Haninger (2nd session)
Interstate Commerce Commission
United States of America

Mr. R. Pometsch (Consultant)
Eurochimie
Belgium

Mr. M. H. Thomas (1st session)
Mr. W. Prosser (2nd session)
Atomic Energy of Canada Ltd.
Canada

Representatives of Specialized Agencies of the United Nations and other Inter-governmental Organizations:

Mr. E. Hellen (1st session)
International Labour Office

Mr. R. Perret
European Nuclear Energy Agency of the O.E.E.C.

Dr. P. Taillard
World Health Organization
DEFINITIONS AND UNITS

1. DEFINITIONS

For the purpose of these Regulations:

1.1. Competent authority

Competent authority of a country shall mean any national or international authority designated or otherwise recognized as such by that country for any purpose in connexion with these Regulations.

1.1.2. Fissile materials

Fissile materials shall mean plutonium-239, plutonium-241, uranium-233, uranium-235, or any material containing any of the foregoing that falls within the definition of radioactive materials below.

1.1.3. Gamma- and/or X-radiation

Gamma- and/or X-radiation shall include all electromagnetic ionizing radiations, such as annihilation radiation, bremsstrahlung, etc.

1.1.4. Maximum credible accident

Maximum credible accident shall mean, in relation to a given mode of carriage, a possible accident or series of accidents, the occurrence of which, although unlikely, must be taken into account in relation to all arrangements in connexion with that mode of transport.

1.1.5. Radiation units

The total of the following dose rates measured at 1 meter from the external surface of a package, at the place where the value is the highest, shall be called the number of radiation units for this package:

(i) for gamma- and/or X-radiation of energy greater than 200 keV: the number of milliroentgens per hour.

(ii) for gamma- and/or X-radiation of which more than 20% has an energy less than 200 keV: the number of milliroentgens per hour multiplied by 3/2.

(iii) for beta-radiation: the number* of milliroentgens per hour which is equivalent.

* It is normal procedure to express beta ray doses in rad in soft tissue; for the purpose of these regulations, however, a dose at any point in soft tissue of 1 rad of beta rays may be taken as equivalent to 1 r of X- or gamma-radiation at the same point.
1.1.6. **Radioactive materials**

Radioactive materials shall mean any material which spontaneously emits ionizing radiation and of which the radioactivity per gram is greater than 0.002 microcurie.

1.1.7. **Vehicles**

Vehicles shall include railroad cars (wagons).

1.2. **UNITS**

1.2.1. **Curie**

The unit of radioactivity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is $3.7 \times 10^{10}$.

A millicurie is one thousandth of a curie.

A microcurie is one millionth of a curie.

1.2.2. **Rad**

The unit of absorbed dose. The absorbed dose of any ionizing radiation is the energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. 1 rad is 100 erg/gram.

1.2.3. **Rem**

The absorbed dose of any ionizing radiation which has the same biological effectiveness as 1 rad of X-radiation with average specific ionization of 100 ion pairs per micron of water, in terms of its air equivalent, in the same region.

1.2.4. **Roentgen**

The quantity of X- or gamma-radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying 1 electrostatic unit of quantity of electricity of either sign.

A milliroentgen is one thousandth of a roentgen.

2. **SCOPE OF THE REGULATIONS**

2.1. These Regulations shall apply to shipments* of radioactive mate-

*Used in the broader American sense throughout these regulations, i.e. consignments, irrespective of the mode of transport.
3. GENERAL PRINCIPLES

3.1. These Regulations aim to control and limit the irradiation and radioactive contamination risks which radioactive materials may present for persons, animals, goods and property in the course of transport.

3.2. The irradiation risks shall be controlled by shielding, distance or duration of exposure, or by a combination of these measures.

3.3. The contamination risks shall be controlled under normal conditions of transport by proper containment of the radioactive materials, careful stowage and limitation of the external contamination of packages. Limitation of the quantities of radioactive materials per package and per shipment and specifications for packaging shall be combined in order to bring within acceptable limits the contamination risks in the case of an accident. Radioactive contamination of the means of transport shall also be controlled and limited.

3.4. The transport of fissile materials shall be subject to additional precautions to prevent a fission chain reaction.

3.5. Adequate labelling or marking shall indicate the presence of radioactive materials and of the potential or actual risks associated therewith.

3.6. The consignor shall provide the carrier and consignee with appropriate information related to the radioactive materials being transported.

4. CONTROL OF EXPOSURE OF PERSONS TO RADIATION

4.1. Persons shall be exposed to radiation as little as practicable.

4.2. Persons shall not be exposed to radiation in excess of the maximum permissible levels laid down in the basic safety standards of the International Atomic Energy Agency (IAEA), which are
to be based, to the extent possible, on the recommendations of the International Commission on Radiological Protection (ICRP). Pending the publication of these basic safety standards by the IAEA, the maximum permissible levels of exposure for various categories of persons shall be those recommended by the ICRP.

4.3. The carrier shall ensure by periodic assessments (which may include tests) that the maximum permissible levels of exposure for various categories of persons are not being exceeded.

4.4. Transport personnel shall not be permitted to receive radiation to the extent permitted for individuals occupationally exposed to radiation¹ unless arrangements have been made to ensure that the conditions of radiation exposure of such workers comply with the relevant provisions that the competent authority has set up for individuals occupationally exposed to radiation.

5. GENERAL PACKAGING REQUIREMENTS

Except as otherwise provided in sections 13, 14, 15 and 16 of these Regulations, the following general conditions of packaging shall apply to all radioactive materials, in pursuance of the aims of the Regulations as set out in section 3:

5.1. CONTAINMENT AND SHIELDING

5.1.1. The packaging shall be such that the radioactive materials cannot readily escape and for this purpose the container shall be leak-proof and securely closed by a positive fastening device. This container shall be enclosed where necessary in a shield adequate to prevent the external dose rate of radiation from exceeding the limits prescribed in section 7 according to the category of the package, or itself be of such construction as to constitute the shield. The shield shall be so constructed and so closed as to prevent unintentional release of the container within; and the packaging shall be such as to ensure that the container will not change its position relative to the shield during transport.

5.1.2. In the construction and design of the container and shield, the following general factors shall be taken into account in the light

¹ As defined in the recommendations of the ICRP, pending the publication of the IAEA basic safety standards.
of the purpose for which the container is to be used and the conditions the package may encounter during such use:

(a) Action of fire, shocks and water;
(b) Corrosion of the container and its closures by the contents;
(c) Effects of changes in temperature and pressure; and
(d) The need to decontaminate surfaces.

5.1.3. Within the above framework the packaging shall be adequate to prevent any loss or dispersal of the radioactive contents and to retain the shielding efficiency under the following conditions:

(a) Type A packaging\* under conditions normally incident to transport and under conditions incident to minor accidents;
(b) Type B packaging\* under conditions normally incident to transport and for the maximum credible accident relevant to the mode of transport.

5.1.4. In the case of type B packaging, the packaging design shall be approved by the competent authority of the country in which the shipment originates. The application to that competent authority for such approval shall indicate the nature of the accident postulated and the design specifications made to withstand the effects of such an accident. The applicant shall be required by that competent authority to give guidance to users on essential loading, unloading, maintenance and inspection requirements. Means shall be provided for applying a seal so that the shipping container cannot be opened without defacing the seal.

5.1.5. In the case of liquid radioactive materials, the following additional requirements shall be met:

5.1.5.1. In type A and type B packaging, the radioactive materials shall be contained in a receptacle which shall itself be enclosed in a container. Both the receptacle and the container shall be leak-proof and securely closed by a positive fastening device. Sufficient ullage shall be left in the receptacle to ensure that there is no build-up of pressure sufficient to disrupt the receptacle.

5.1.5.2. In type A packaging, the receptacle shall be surrounded by enough absorbent material to absorb the entire contents. This absorbent material shall be interposed between the receptacle and the container. In addition, when the receptacle is made of

\* Packages in each one of the categories white and yellow defined in section 7 can be either of type A or of type B packaging according to the needs and circumstances.
material which may readily break or puncture, the absorbent material shall provide efficient cushioning.

5.1.5.3. In type B packaging, when the receptacle is made of material which may readily break or puncture, the receptacle shall be surrounded by enough absorbent material to absorb the entire contents. This absorbent material shall be interposed between the receptacle and the container. When the receptacle is not made of material which may readily break or puncture, this absorbent material may be dispensed with subject to the approval of the competent authority of the country in which the shipment originates.

5.1.5.4. The absorbent material referred to in sub-paragraphs 5.1.5.2. and 5.1.5.3. above shall be of such a nature that its efficiency would not be impaired by chemical reaction with the contents of the receptacle.

5.1.6. Within the general provisions for type B packaging set forth in paragraphs 5.1.1. to 5.1.5. above, and besides other design features which may be required to meet these provisions, the design of type B packaging shall, in particular, incorporate minimum safety features equivalent to those given in the packaging note, Annex I.

5.2. MINIMUM DIMENSIONS OF PACKAGES

The smallest external dimension of the total packaging assembly shall not be less than 10 cm (4 in).

5.3. SPECIAL REQUIREMENTS FOR HEAVY PACKAGES

5.3.1. Heavy packages shall be so designed that they can be properly secured to the conveyances during transport.

5.3.2. Heavy packages must be fitted with hooks, skids or any other device necessary to distribute the load and facilitate normal handling. In the case of air transportation, packages having a floor bearing weight over 0.034 kg/cm² (70 lb/ft²) will be subject to advance arrangements with the air carriers involved in the transport.

5.3.3. Packages of the yellow category (see section 7) weighing more than 5 kg must be fitted with handles.

5.3.4. Any package of a gross weight of 1'000 kg [1 t (metric)] or more shall have its weight plainly and durably marked on the exterior of the package before being offered for transport.
5.4. A package of radioactive materials shall not contain any other goods, with the exception of instruments or apparatus for use with these materials.

6. LIMITATION OF QUANTITIES OF RADIOACTIVE MATERIALS IN A PACKAGE

6.1. CLASSIFICATION OF RADIOISOTOPES

For the purpose of these Regulations radioisotopes are divided into three groups according to their radiotoxicity:

- Group I: very high radiotoxicity
- Group II: high radiotoxicity
- Group III: moderate or low radiotoxicity

An alphabetical listing of their classification is given in Table IV, Annex I. Any radioisotope not listed in this table shall be considered as belonging to Group I.

6.2. MAXIMUM RADIOACTIVITY IN A PACKAGE

6.2.1. General provisions

The following limitations on the total activity in any one package shall apply to all shipments of radioactive materials which are not shipments of large radioactive sources as defined in paragraph 6.2.3. below or shipments otherwise exempted under the provisions of section 13.

6.2.1.1. Radioactive materials in the form of a non-friable, massive solid of melting point equal to or greater than 538°C (1000°F) and non-soluble in water and non-reactive with air or water:

Total activity (irrespective of the groups of radiotoxicity to which the materials involved belong):

- In type A packaging: up to 20 c
- In type B packaging: up to 2000 c

6.2.1.2. Pyrophoric radioactive materials

In type B packaging only, up to the limits specified in sub-paragraph 6.2.1.5. below for type B packaging.

6.2.1.3. Explosive radioactive materials

Not permitted for transportation except under special arrangements as provided in section 17.
6.2.1.4. **Radioactive materials of low specific activity**

Activities to be limited in accordance with the provisions of this section or the materials to be transported according to the provisions of section 14.

6.2.1.5. **Other radioactive materials**

<table>
<thead>
<tr>
<th>Maximum activity in a package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group of the radioisotope</td>
</tr>
<tr>
<td>Type of packaging</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
</table>

For the purposes of this sub-paragraph, the following rules shall be applied in the case of a mixture of radioisotopes:

(a) If the nature of the radioisotopes involved is not known, the maximum activity in a package shall be limited to:
   - 100 µc for type A packaging;
   - 20 c for type B packaging;

(b) If the nature of all radioisotopes involved is known, but not the relative amount of their activities, the maximum activity in a package shall be limited to the figure given for the Group of radioisotopes involved, the radiotoxicity of which is the highest;

(c) If the nature and relative amount of activity of all radioisotopes involved is known, the maximum total activity in a package shall be determined by the appropriate one of the following formulae:

   for type A packaging:
   
   \[(\text{total activity in mc of Group I}) \times 100 + (\text{total activity in mc of Group II}) + (\text{total activity in mc of Group III}) \times 1/200\]

   shall be equal to or less than 10 mc;

   for type B packaging:
   
   \[(\text{total activity in c of Group I}) + (\text{total activity in c of Group II}) + (\text{total activity in c of Group III}) \times 1/10\]

   shall be equal to or less than 20 c.

6.2.2. **Special provisions for fissile materials**

* See definition of fissile materials in section 1.
In addition to the limitations of paragraph 6.2.1. above, shipments of radioactive materials which are also fissile materials shall comply with the provisions of section 15, except for shipments as provided below:

6.2.2.1. Shipments containing in any one package quantities\* of fissile material equal to or less than those specified as follows:

<table>
<thead>
<tr>
<th>Fissile materials</th>
<th>Quantity in a package**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plutonium</td>
<td>9 g</td>
</tr>
<tr>
<td>$U^{233}$</td>
<td>16 g</td>
</tr>
<tr>
<td>$U^{235}$ (except as provided in sub-paragraph 6.2.2.2.)</td>
<td>16 g</td>
</tr>
</tbody>
</table>

Where a package is to contain more than one kind of fissile material, the applicable quantity limit for the package shall be calculated by means of the following formula:

\[
(g \text{ Pu}) \times 16 +
(g \text{ U}^{233}) \times 9 +
(g \text{ U}^{235}) \times 9
\]

shall be equal to or less than 144 g.

6.2.2.2. Shipments in which the only fissile material present is uranium in which the $U^{235}$ content is no higher than 0.72\% by weight, provided that packages containing such materials do not contain more than trace quantities of beryllium, graphite (pile-grade) or heavy water.

6.2.2.3. Shipments of aqueous or other solutions in which the only fissile material present is:

(a) Uranium, in any enrichment, in which the $H : U^{235}$ atomic ratio is greater than 5 200, corresponding to a $U^{235}$ concentration in common aqueous solutions of less than 5 g/l; or

(b) Plutonium in which the $H : Pu^{239}$ atomic ratio is greater than 7 600, corresponding to a $Pu^{239}$ concentration in common aqueous solutions of less than 3.5 g/l, provided that the material being transported is such that homogeneity will be assured at all times, and that no portion in the solution will be, at any time during transport, in excess of that concentration. Consideration shall be given to the effects of freezing and evaporation.

\* Table XI, Annex I, indicates the activity-mass relationships.

\** See explanatory statement in Annex III.
6.2.3. **Shipment of large radioactive sources**

Radioactive materials, the activity of which is greater than the applicable value set out below, which are to be transported in a single package shall be considered to be a large radioactive source and shall be transported in compliance with the requirements of section 16;

(a) 20 c of radioactive materials of Group I or Group II; or
(b) 200 c of radioactive materials of Group III; or
(c) 2 000 c of radioactive materials in the form of a non-friable, massive solid of melting point equal to or greater than 538 °C (1 000 °F) and non-soluble in water and non-reactive with air or water.

7. **LIMITATION OF EXTERNAL RADIATION DOSE-RATE**

Packages containing radioactive materials shall be divided into two categories:

7.1. **“WHITE” CATEGORY**

A package such that the dose-rate of the radiation originating from the radioactive materials or from any part of the aggregate constituting the complete package, at any point on the external surface of the shipping container at any time during transport, shall not exceed:

(a) 10 mr/24 h for gamma- and/or X-radiation;
(b) the equivalent of 10 mr/24 h for beta-radiation*;
(c) those values of flux given in Table I, Annex I, for neutrons.

The limits for dose-rates referred to in this sub-section 7.1. for each type of radiation are considered to be equivalent in biologi-

* It is normal procedure to express beta-ray doses in rad in soft tissue. However, for the purpose of these Regulations a dose at any point in soft tissue of 1 rad of beta rays may be taken as equivalent to 1 r of X- or gamma-radiation at the same point.

In practice the scale of beta-gamma dosimeters is often graduated in r/h or mr/h (through calibration of the device by the constructor, using gamma rays). In certain cases only will the reading, when the device is exposed to beta rays, read directly in equivalent roentgen. It is desirable that an instrument on which beta- and gamma-radiations can both be read directly should be used.
7.2. "YELLOW" CATEGORY

A package which, not falling within the limits laid down for the "WHITE" category, fulfils at any time during transport the conditions listed within paragraphs 7.2.1. and 7.2.2. following:

7.2.1. The dose-rate of the radiation originating from the radioactive materials or from any part of the aggregate constituting the complete package, at any point on the external surface of the shipping container, shall not exceed:

(a) 200 mr/h for gamma- and/or X-radiation;
(b) the equivalent of 200 mr/h for beta-radiation;
(c) those values of flux given in Table II, Annex I, for neutrons.

The limits for dose-rates referred to in this paragraph 7.2.1. for each type of radiation are considered to be equivalent in biological effectiveness; therefore, if more than one of these types of radiation is present, the total dose-rate shall not exceed the equivalent of one of the above limits.

7.2.2. The dose-rate of the radiation originating from the radioactive materials, or from any part of the aggregate constituting the complete package, at 1 m from any external surface of the shipping container will not exceed:

(a) 10 mr/h for gamma- and/or X-radiation;
(b) the equivalent of 10 mr/h for beta-radiation;
(c) those values of flux given in Table III, Annex I, for neutrons.

The limits for dose-rates referred to in this paragraph 7.2.2. for each type of radiation are considered to be equivalent in biological effectiveness; therefore, if more than one of these types of radiation is present, the total dose-rate shall not exceed the equivalent of one of the above limits.

7.3. MEASURING INSTRUMENTS

Dose-rates of radiation specified in this section shall be measured with instruments of types approved by the competent authority of the country in which the shipment originates.
8. LABELLING AND MARKING

8.1. LABELLING AND MARKING OF PACKAGES AND CONTAINERS

8.1.1. Any package containing radioactive materials shall bear labels which shall be affixed to two opposite sides. These labels shall conform to one of the models below according to the category of the package as defined in section 7. The only inscriptions on the labels which shall be mandatory shall be those indicated in these models (Figs. 1 and 2).

---

**Fig. 1**
Category WHITE Packages

**Note:** Dimensions given here are the actual ones to be used.
Fig. 2
Category YELLOW Packages

**Note:** Dimensions given here are the actual ones to be used.

8.1.2. The outermost container shall, whenever possible, be plainly marked by embossing, stamping or other means with the trefoil and skull-and-crossbones sign shown in the model referred to in paragraph 8.1.1. in such a way that the mark is resistant to fire and water.

8.1.3. Labelling and marking of packages and containers shall be the responsibility of the consignor.
8.2. LABELLING OR OTHERWISE MARKING OF VEHICLES

8.2.1. All vehicles containing shipments of radioactive materials shall be clearly labelled or otherwise clearly marked.

8.2.2. This labelling or marking shall be black on a white background and as shown in Fig. 3.

Note: A solid border-line shall be placed at 45° to the wording as shown above. The overall shape of the marking may be diamond, rectangular or square as indicated by the dashed lines. Minimum dimensions are given; when larger dimensions are used, the relative proportions must be maintained.
8.2.3. Any road vehicle carrying radioactive materials shall carry in the driver's compartment a notice worded as follows:

**WARNING**

**THIS VEHICLE IS CARRYING**

**RADIOACTIVE MATERIALS**

**PROVIDED THEY ARE UNDAMAGED**

**THE PACKAGES ARE SAFE TO HANDLE FOR**

**SHORT PERIODS**

Whenever appropriate, this notice shall indicate the person or authority to communicate with in case of accident.

8.2.4. The provisions of paragraphs 8.2.1. to 8.2.3. above shall not apply:

8.2.4.1. to ships and aircraft; or

8.2.4.2. in the case of express shipments conveyed by passenger trains where the packages are in the direct custody of the guard.

9. TRANSPORT DOCUMENTS

9.1. INFORMATION REQUIRED

The articles shall be entered on the transport documents as radioactive materials.

In addition, the following information shall be entered on the transport documents:

(a) Group or groups of toxicity: I, II or III;

(b) A description of the nature and the physical and chemical form of the radioactive contents;

(c) Category of package (white or yellow) and all particulars listed on the corresponding label;

(d) The highest value of the dose-rate* at the surface of the shipping container;

(e) The type of packaging (A or B); and

(f) Any other special instructions which are necessary to ensure safe transport, handling, storage or disposal of the shipment.

9.2. CERTIFICATION BY CONSIGNOR

The transport documents shall, in addition, include certification

---

* Expressed in the units indicated in section 7.
under the written signature or stamped facsimile of the consignor or his duly authorized agents, in the following terms:

"This is to certify that the above-named articles are properly described and are packed and marked in accordance with international regulations and are in proper condition for transport."

The carrier may also request the consignor to have the above statement certified by the competent authority of the country in which the shipment originates. When the consignor states that the article does not fall within the scope of these Regulations, the carrier may require the consignor to certify this statement.

9.3. LANGUAGE(S) TO BE USED IN THESE DOCUMENTS

In case of transport through countries having different languages, the transport documents shall be written in such languages as might be required for understanding by the carriers concerned.

10. LOADING AND STORAGE

10.1. SECURE STOWING

Shipments of radioactive materials shall be securely stowed.

10.2. LIMITATION OF THE NUMBER OF PACKAGES

10.2.1. Not more than 50 packages with white or yellow labels shall be in any one vehicle or aircraft at one time. These may be either all white label

or

all yellow label

or

a combination of both.

This limitation shall not apply to carriage by water except that no more than 50 packages with white or yellow labels shall be carried in any one hold and, further, that no more than two Class II shipments of fissile material (see 15.2.2.) shall be carried on one vessel.

10.2.2. The number of packages with yellow labels in any one vehicle or aircraft at one time shall be so limited that the total number of radiation units indicated on those labels does not exceed 40. This limit is raised to 400 radiation units for carriage by water. Prior approval shall be obtained from the appropriate competent
authority if it is proposed to convey more than 400 such units in one vessel.

10.2.3. The number of packages with \textit{yellow} labels stored in any one place, such as a terminal or storeroom, shall be limited so that the total number of radiation units indicated on the labels does not exceed 40, unless special provisions are made for radiation safety.

10.3. \textbf{PROHIBITION ON MIXED LOADING OR STORAGE}

10.3.1. In general, radioactive materials shall not be stowed in the same vehicle or compartment as substances which are either explosive, inflammable, corrosive, oxidizing, or which are spontaneously inflammable, or which are compressed or liquefied gases.

10.3.2. Railroad cars containing radioactive materials shall not be placed next to railroad cars containing explosives.

10.3.3. Packages containing radioactive materials and packages containing undeveloped films or plates shall be kept separated at a safe distance\textsuperscript{a}.

10.4. \textbf{PROTECTION OF PERSONS}

10.4.1. No package of the \textit{white} or \textit{yellow} category shall be carried in compartments occupied by passengers.

10.4.2. No package of the \textit{yellow} category shall be placed in any conveyance, terminal, or other place closer than indicated in Table VII or Table VIII, Annex I, to an area which may be continually occupied by persons. In addition the provisions of section 4 shall be observed.

11. \textbf{RADIOACTIVE CONTAMINATION OF CONVEYANCES AND OF THE OUTER SURFACES OF PACKAGES}

11.1. When a package is handed over for transport, the radioactive contamination shall not exceed, on any external surface of the package, the levels prescribed in Table X, Annex I.

11.2. In the event of a shipment of radioactive materials suffering breakage or leakage, or becoming involved in a crash, wreck or fire, the affected area shall be isolated to prevent all contact\textsuperscript{a}

\textsuperscript{a} Tables V and VI, Annex I, indicate safe distances for films according to the number of radiation units and the duration of transport.
of persons with any loose radioactive material and, when practicable, posting or fencing shall be provided. No persons shall be allowed to remain within the isolated area until qualified persons are available to check radiation hazards and supervise the handling or salvage. The consignor and appropriate authorities shall be notified immediately. Notwithstanding anything in this sub-section, the presence of radioactive material should not be taken, however, as a bar to rescue operations or fighting of fire by qualified persons.

Any person who may have become contaminated with radioactive materials shall be subject to appropriate control and examination measures.

11.3. If radioactive materials have leaked or have been spilled or otherwise dispersed in any conveyance, building, area or equipment used for transport or storage, qualified persons shall be called in to direct the decontamination work as soon as possible. Such conveyance, building, area or equipment shall not be put into service until declared safe for use.

12. CUSTOMS

Customs operations which require examination of the contents of a package in which radioactive materials are being shipped, shall be carried out in an area where means of radiation exposure control are provided. Any package which is opened on customs instructions before reaching the consignee at its final destination shall be restored to its original condition.

13. EXEMPTIONS FROM THE REGULATIONS CONTAINED IN SECTIONS 5 TO 12

13.1. CONDITIONS OF EXEMPTION OF GROUP I MATERIALS
Except as set forth in sub-sections 13.3. and 13.4. and in section 14 below, the transport of Group I radioactive materials shall not be exempted from the regulations of sections 5 to 12.

13.2. CONDITIONS OF EXEMPTION OF GROUP II AND GROUP III MATERIALS
The transport of Group II or Group III materials shall be exempted from the regulations in sections 5 to 12 in so far as
13.2.1. The package does not contain more than:
   (a) 0.1 mc of Group II material or
   (b) 1 mc of Group III material;

13.2.2. The package is such that there can be no leakage of radioactive materials under conditions normally incident to transport;

13.2.3. The package is such that the radiation dose-rate at any point on its external surface at any time during transport does not exceed the limits given in sub-section 7.1. for category white packages;

13.2.4. The provisions of sub-section 11.1. above are observed; and

13.2.5. For fissile material, the quantity in the package does not exceed the limits specified in sub-paragraph 6.2.2.1. and the dimensions of the package conform to the requirements of sub-section 5.2.

13.3. RULES FOR INSTRUMENTS WITH RADIOACTIVE MATERIALS AS COMPONENTS

Notwithstanding the provisions of sub-section 13.1., the transport of instruments, clocks, electronic tubes or apparatus, or similar manufactured goods, of which radioactive material in a non-readily dispersable form is a component part, shall be exempted from the regulations in sections 5 to 12 in so far as they are not expressly retained in this sub-section, if these goods are securely packed in strong shipping containers and in accordance with the provisions of paragraph 13.2.3.

13.4. EMPTY PACKAGES

The regulations in sections 5 to 12, in so far as they are not expressly retained in this sub-section, shall not apply to empty packages which have contained radioactive materials if all the following conditions are fulfilled:

13.4.1. The receptacle which contained the radioactive material has been decontaminated and the remaining contents are estimated not to exceed:

   (a) For Group I material:
       1 mc if assessed in quantity, or
       $10^{-4} \mu\text{c/cm}^2$ if assessed as a contamination level;

   (b) For Group II material:
       0.1 mc; or

   (c) For Group III material:
       1 mc.
13.4.2. The transport documents shall show that the package has contained radioactive materials. The consignor shall certify in writing that the provisions of paragraph 13.4.1. above have been met.

13.4.3. The provisions of sub-section 11.1 and paragraph 13.2.3. above shall be met and the empty package shall be in good condition and securely closed.

14. TRANSPORT OF RADIOACTIVE MATERIALS OF LOW SPECIFIC ACTIVITY

14.1. Shipments of radioactive materials which belong to one of the categories specified in paragraphs 14.1.1. and 14.1.2., and in paragraphs 14.1.3. and 14.1.4. subject to the proviso contained in paragraph 14.1.5., and which comply with the requirements set forth in this section, shall be exempted from the packaging and labelling requirements of sections 5, 6 and 7 and sub-section 8.1.

14.1.1. Unirradiated uranium, containing 0.72% U\(^{235}\) by weight, or less, and unirradiated thorium, in a non-friable, massive-solid form or contained in an inert metal cover or other substantial coating such that the surface of the uranium or thorium is not exposed\(^6\), provided that:

(a) the radioactive materials are packed in a manner which will prevent the ingress of moisture and movement of the material within the package or vehicle; and

(b) beryllium, graphite (pile-grade) or heavy water are not included in the package containing the radioactive materials.

14.1.2. Ores and concentrates (of ores) of natural uranium and natural thorium;

14.1.3. Intermediate products, i.e. in-process materials in gaseous, liquid, sludge or solid form arising from the processing of natural uranium and thorium before enrichment or irradiation of the uranium or thorium, but not including refined isotopes of radium.

14.1.4. Low-activity materials, i.e. residues from the processing of natural uranium and thorium; wastes such as building rubble, metal, wood and fabric scrap, glassware, paper and cardboard;

\(^6\) For instance, aluminium-clad fuel elements.
reactor and process plant wastes in liquid or solid form; sludges and ashes from incinerators containing radioactive materials; or other materials, provided that, in such low-activity materials, the estimated maximum radioactivity content for radioactive materials in Group I does not exceed:

- 0.1 $\mu$Ci/g in the case of radioactive material in sludge or solid form; or
- 0.1 $\mu$Ci/ml in the case of radioactive material in liquid form;

where radioactive materials in Group I are not present, the limits shall be, respectively, 1.0 $\mu$Ci/g and 1.0 $\mu$Ci/ml.

14.1.5. In the case of intermediate products and low-activity materials, or of ores and concentrates (of ores) of natural uranium and natural thorium, shipments shall be made in such form and quantity that the estimated total radioactive content of any one container, vehicle or compartment does not exceed:

- 100 millicurie (mc) of any material in Group I;
- 1 curie (c) of any material in Group II;
- 20 c of any material in Group III; or

for any combination of radioactive materials involving more than one toxicity group:

\[(\text{total activity in mc of Group I}) \times 10 + \]
\[(\text{total activity in c of Group II}) + \]
\[(\text{total activity in c of Group III}) \times 1/20 \]

shall be equal to or less than 1 c.

14.2. The radioactive materials listed in sub-section 14.1. shall be packed in strong, leak-proof packages or loaded in vehicles or compartments specially designed to ensure that there will be no leakage under conditions normally incident to transport.

14.3. There shall be no loose radioactive materials in any conveyance. In the case of specially designed conveyances or compartments referred to in sub-section 14.2., these conveyances or compartments shall not be used for transport of other goods until decontaminated to the levels specified in Table X, Annex I.

14.4. The consignor or consignee shall ensure that the conditions of packaging, loading and unloading for which they are responsible are such that operating personnel are not likely to be exposed to doses of radiation in excess of the permissible levels referred to in sub-section 4.2.

14.5. The shipment shall be loaded so as to prevent loss or dispersion or shift of lading under conditions normally incident to transport.
14.6. Shipments shall be loaded and unloaded by or under the direct supervision of the consignor or of the consignee. In the case of trans-shipment, however, the consignor or consignee shall, where necessary, make other arrangements to ensure compliance with the requirements of section 14.

14.7. ADDITIONAL PROVISIONS

14.7.1. Shipments by sea and inland waterways
Stowage shall comply with the following requirements:

14.7.1.1. The stow shall be as cubic in shape as possible.
14.7.1.2. Shipments shall not be carried in the same compartment with foodstuffs.

14.7.1.3. Shipments of low-activity materials shall comply with the separation distances given in Table VI, Annex I, for the purposes of which the number of radiation units shall be taken as the highest radiation level in mr/h (or equivalent) at a distance of 1 m from the outer surface of the shipment.

14.7.1.4. All other shipments made under the provisions of section 14:
(i) shall be separated from any living accommodation by both:
   (a) a distance of at least 3 m (10 ft); and
   (b) at least one steel deck or bulkhead at least 0.5 cm (3/16 in) thick;
(ii) shall be separated by an intervening hold or compartment from undeveloped films or plates.

14.7.1.5. Before unloading, the compartment in which the shipment has been carried shall be adequately ventilated to remove gases which may have collected.

14.7.2. Shipments by rail or road including the use of ferries by rail or road vehicles

14.7.2.1. Such shipments shall be in full truck-load or car-load lots.
14.7.2.2. In the case of transport by road:
(i) the X- or gamma-radiation or equivalent shall not exceed 200 mr/h at any readily accessible exterior surface of the vehicle nor 10 mr/h at a distance of 2 m (6 ft) from such surface.
(ii) the number of mr/h, or equivalent, at 1 m from the surface of the shipment nearest to the driver’s compartment shall not exceed the number of radiation units applicable under Table VIII according to the separation distance between the driver’s compartment and that surface and to the duration of carriage.
14.7.2.3. In the case of transport by rail the X- or gamma-radiation or equivalent shall not exceed 200 mR/h at any readily accessible exterior surface of the vehicle nor 10 mR/h at a distance of 3 m (10 ft) from any surface of the vehicle and 10 mR/h at a distance of 1.6 m (5 ft) from either end-surface of the car.

14.7.2.4. In the case of transport by rail or road, the vehicle shall be labelled or marked in accordance with sub-section 8.2.

14.7.3. **Shipments by air**
Such shipments shall be made only under special arrangements which shall comply with sub-sections 14.1. to 14.6.

15. **FISSILE MATERIALS**

15.1. **SCOPE**

15.1.1. Except as provided in paragraph 6.2.2., shipments containing fissile materials, as defined in section 1, shall be made in compliance with the conditions specified in this section.

15.1.2. Should regulations exist for a particular mode of transport requiring the conclusion of a special agreement for a shipment of fissile material, such special agreement shall, so far as possible, incorporate the provisions of this section of the regulations.

15.1.3. In addition to the conditions set forth in this section for criticality control (nuclear safety) essential to the safe shipment of fissile materials, such shipments shall also comply with any other applicable provisions of the regulations.

15.1.4. The criteria given for nuclearly safe shipments (i.e., Classes I and II) in this section are necessarily general. For a specific shipment, the criteria may not be applicable or may lead to unnecessarily restrictive shipping requirements. For such cases, a nuclear safety specialist, by application of special controls relating to the specific shipment (i.e., under Class III), may provide adequate nuclear safety even though the more restrictive criteria are not met.

15.2. **CLASSES OF SHIPMENTS OF FISSILE MATERIALS**

15.2.1. **Class I — Shipments in packages such that each package is safe from neutron interaction in any arrangement**
This means that a critical assembly will not be formed when any number of such packages are stacked together in any manner.
15.2.1.1. To be considered in this class packages shall comply with the design specifications for criticality control in Annex II.

15.2.1.2. When shipments are made in such packages, no special shipping arrangements or instructions are necessary in regard to their nuclear safety other than certification as provided in sub-section 15.5.

15.2.2. **Class II — Shipments in packages which, because of limited numbers and limits on contents, are nuclearly safe in any arrangement**

In this class the number of packages which are allowed to be shipped together is so limited that a critical assembly would not be formed in any credible circumstances even if five times the allowable number were to collect together.

15.2.2.1. Packages shall comply with a design specification for criticality control laid down in Annex III.

15.2.2.2. The maximum amount of fissile material for any one package and the allowable number of such packages shall be determined by the procedures laid down in Annex III. The smallest external dimension of the total packaging assembly for packages in this class shall not be less than 15 cm (6 in).

15.2.2.3. The consignor shall introduce on one mode of transport, during any twenty-four hour period, no more than the allowable number of such packages as determined by the procedures laid down in Annex III.

15.2.2.4. In addition, the consignor shall introduce no more than 50 such packages at any one time on one mode of transport.

15.2.2.5. When shipments are made in accordance with the limits provided for in this class, no special shipping arrangements or instructions are necessary other than certification as provided in sub-section 15.5.

15.2.3. **Class III — Shipments under special arrangements**

15.2.3.1. All shipments of fissile material in quantities or under conditions which do not meet all of the specifications for any one of the two classes above shall be made only by special arrangement, in accordance with the provisions of section 17.

15.2.3.2. Such shipments shall be made under conditions which meet the general requirements of sub-section 15.3.

15.2.3.3. Packages used for shipments in this class shall be designed and constructed so that, under the conditions established for carriage of those packages, the shipment shall be nuclearly safe at all
times during transport (including the case of the maximum credible accident) and so that the original configuration, concentration or other physical factors contributing to the criticality control of the fissile materials concerned shall be maintained during the entire transit period.

15.2.3.4. Consideration shall be given to the effects of the proximity of other types of material and of neutron interaction with similar shipments. When other shipments must not be shipped with a Class III shipment, a specific restriction shall be provided in the special arrangement and an instruction to that effect issued with the transport documents.

15.3. GENERAL REQUIREMENTS FOR THE CARRIAGE OF FISSILE MATERIALS (INCLUDING UNIRRADIATED AND IRRADIATED FUEL)

15.3.1. **Type of packaging and criticality conditions**
All fissile materials shall be packaged for shipment in packages designed and constructed to meet the specifications for type B packaging and in such a manner that conditions of criticality cannot be reached under conditions encountered in transport.

15.3.2. **Additional requirements for Class III shipments**
Class III shipments, in addition to other applicable provisions, shall comply with the following provisions:

15.3.2.1. Controls shall be such that an unsafe configuration of fissile materials cannot be attained in the absence of a double contingency* and positive action shall be taken to prevent such contingencies arising.

15.3.2.2. In regard to any materials which may act as a moderator or a reflector, the nuclear safety of the shipment shall be assessed by assuming credible conditions for the shipment, but in circumstances which produce the maximum reactivity.

(a) The credible conditions to be considered shall include the possibility of the shipment's becoming immersed in water as the result of an accident or from some other cause. Shipments shall be so packaged and braced that they will remain

* A single change in the shipping conditions must not result in critical conditions, but rather it must require the occurrence of at least two unlikely, independent and simultaneous changes in one or more of the conditions originally specified as essential to nuclear safety before a nuclear accident is imminent. This is the application of the double contingency principle.
safe in such circumstances. Furthermore, unless the entire package is constructed to remain water-tight in the event of the maximum credible accident, the package shall be so designed that nuclear safety will be ensured even though it becomes partially or completely filled with, and surrounded by, water.

(b) In the case of fissile materials in the form of nuclear fuel elements, the conditions which shall be assumed for maximum reactivity are the following, taken singly or in combination:

(i) dry shipment;
(ii) water filling all spaces in and around the fuel elements;
(iii) partial or total loss of the water or other coolant;
(iv) container partially or totally surrounded by water.

15.3.2.3. In order that nuclear safety may be maintained, interaction with other loads and with other materials shall be taken into consideration, possible accident conditions always being included. Such consideration shall include:

(a) The possibility that two shipments may be intermingled;
(b) The possibility that a shipment may be adjacent to another shipment, which latter contains materials with neutron-reflecting and moderating properties greater than those of water (e.g. beryllium, graphite, or heavy water); and
(c) The need for bracing and dunnage adequate to prevent the coming together of individual units in a shipment, in cases where nuclear safety depends upon the spacing of these units.

15.3.3. Fissile materials in the form of nuclear fuel elements

15.3.3.1. In evaluating the inherent safety of the shipment one of the following alternative approaches shall be used; either

(a) The effective neutron multiplication factor \( k_{eff} \) of the system shall not exceed 0.9; or

(b) The following safety factors shall be applied to allow for uncertainties in the experimental or calculated data used:

(i) where mass is the controlling factor, the permissible value in any single package must not exceed 80% of the critical mass under the conditions of packing, with due consideration for built-in neutron absorbers; or

(ii) where geometry is the controlling factor, the permissible value for each controlling dimension must incorporate a 10% safety factor.
15.3.3.2. The spacing between fuel elements shall be assumed to be that which gives the maximum reactivity. In cases where other than this configuration is assumed, the container shall be so designed, and the fuel elements so supported within the container, that the fuel elements cannot, as a result of the maximum credible accident, be rearranged into a configuration more reactive than that for which the shipment is designed.

15.3.3.3. Structural materials, such as components of the shipping container or other incidental neutron absorbers which are not constituents of the package or of the fuel elements, the presence of which cannot be ensured throughout the transport period, shall not be considered as neutron absorbers which contribute to the criticality control. Additional built-in neutron absorbers may be considered, provided there is assurance that such absorbers cannot change their effectiveness or their position relative to the fuel elements, e.g. by mechanical shock or meltdown, during normal shipment or as a result of the maximum credible accident. Where such built-in neutron absorbers are considered, periodic tests shall be made to confirm their presence and effectiveness. Such tests shall also be made following an accident or in those cases where the effectiveness or position of the neutron absorber may have been changed by corrosive action.

15.3.4. Irradiated fissile material (with special reference to irradiated nuclear fuel elements)

Shipments of irradiated fissile materials shall be made in accordance with all applicable provisions of the regulations with particular reference to section 16. For criticality control, in addition to compliance with the other applicable provisions of this section, particularly those of paragraph 15.3.3., the following assumptions shall be made, where applicable, in determining the critical mass:

15.3.4.1. Fuel which has been so irradiated that its reactivity decreases with burn-up shall for this purpose be regarded as unirradiated. Irradiated fuel in which reactivity increases with burn-up shall be regarded as irradiated fuel at the point of maximum reactivity.

15.3.4.2. The fuel shall be considered as melted fuel in the most reactive array, unless it has been demonstrated that meltdown of the fuel element cannot occur as a result of internal heating or as a result of the maximum credible accident.

15.3.5. Miscellaneous fissile materials (such as residues or scrap)

The shipment of fissile materials, of which the enrichment, mass,
concentration, moderator ratio, or density is not accurately known or cannot be positively identified, shall be made under conditions which are nuclearly safe and in compliance with the applicable provisions of these regulations, on the assumption that each parameter that is not exactly known is that giving the maximum reactivity under credible conditions.

15.4. CERTIFICATION OF NUCLEAR SAFETY

15.4.1. Approval procedure for Class I

15.4.1.1. Approval of the packaging as meeting the requirements of this section for Class I shipments shall be obtained from the competent authority of the country in which the shipment originates.

15.4.1.2. The application for such approval shall include

(a) detailed information on:
   (i) The maximum quantity, physical state, and chemical and isotopic composition of the fissile materials to be shipped in each container; and
   (ii) The shipping container specifications;

and

(b) A statement that the packaging satisfies the criticality control specifications of Annex II.

15.4.1.3. Upon approval the competent authority shall issue a document stating that the packaging satisfies the requirements of these regulations and is allowed for the form and quantity of the fissile materials specified. This document shall be interpreted as meaning that the application has been reviewed by a qualified nuclear safety specialist and that he has determined that the packaging complies with the requirements of Annex II and, unless otherwise noted, meets the general requirements of these regulations.

15.4.2. Approval procedure for Class II

15.4.2.1. Approval of the packaging as meeting the requirements of this section for Class II shipments and certification that, for the contents and package volume, the number of packages as determined is allowed for the mode of transport shall be obtained from the competent authority of the country in which the shipment originates.

15.4.2.2. The application for such approval shall include

(a) Detailed information on:
   (i) The maximum quantity, physical state, and chemical and isotopic composition of the fissile materials to be shipped in each container;
15.4.2.3. Upon approval, the competent authority shall issue a document stating that the packaging satisfies the requirements of these regulations, is permitted for the form and quantity of the materials specified and may be delivered in the allowed numbers to a mode of transport. This document shall be interpreted as meaning that the application has been reviewed by a qualified nuclear safety specialist and that he has determined that the packaging complies with the requirements of Annex III and, unless otherwise noted, meets the general requirements of these regulations.

15.4.3. **Approval procedure for Class III**

15.4.3.1. Approval shall be obtained from the competent authority of the country in which the shipment originates for each shipment of fissile materials under Class III.

15.4.3.2. The application for such approval shall include detailed information on:

(a) The maximum quantity, physical state, and chemical and isotopic composition of the fissile materials to be shipped in each container;

(b) The shipping container specifications;

(c) The number of containers to be shipped;

(d) The safety measures to be taken to ensure that containers will not come into hazardous proximity with one another or with containers of another shipment of special nuclear materials;

(b) A statement that the packaging satisfies the criticality control specifications of Annex III.
(e) The mode of transport to be used;

(f) The applicant’s own evaluation of the adequacy of the proposed procedures to provide protection against accidental conditions of criticality, taking into account the possibility of accidents, including flooding, fire and wreckage; and

(g) Reasons for requesting the special arrangement for the shipment and complete details of the basis on which the nuclear safety of the shipment will be ensured.

15.4.3.3. Upon approval, the competent authority shall issue a document stating that the shipment is in all respects in accordance with these Regulations and is allowed for the mode of transport to be used. The document may also list the conditions under which the movement is to be made, such as routing, transfer points, final destination and any special precautions to be observed.

15.4.3.4. In addition, approval shall be obtained for the special arrangement in accordance with the provisions of section 17.

15.5. TRANSPORT DOCUMENTS

In addition to the certification required under sub-section 9.2 of these Regulations, the consignor shall certify on the transport documents for each shipment of fissile materials:

(a) The class to which the shipment belongs; and

(b) That the shipment meet the conditions laid down in the document issued by the competent authority for the container being used.

In addition, for Class III shipments, the consignor shall attach to the transport documents a copy of the approval document issued by the competent authority.

16. LARGE RADIOACTIVE SOURCES*

16.1. SCOPE

16.1.1. Unless otherwise specified in this section, shipments of large radioactive sources as defined in paragraph 6.2.3. shall be transported in accordance with the requirements of this section and all other provisions of these Regulations.

16.1.2. In addition, all shipments of large radioactive sources containing fissile materials, e.g. irradiated nuclear fuels, shall meet the

* See paragraph 6.2.3.
requirements laid down in paragraph 6.2.2. or in section 15 for control of conditions of criticality.

16.2. PACKAGING REQUIREMENTS FOR LARGE RADIOACTIVE SOURCES

16.2.1. Type of packaging and approval
Packaging for the transport of large radioactive sources shall meet the type B packaging specifications and shall have been approved by the competent authority of the country in which the shipment originates.

16.2.1.1. Complete information concerning the shipping container shall be submitted in the application for approval. This information shall include:

Details of the use for which the shipping container has been designed; in particular the type, form and maximum amount of radioactive materials which the shipping container is designed to carry.

The shipping container specifications. These shall include:
- a sketch or drawing of the container showing the dimensions; the design data, in particular the shielding calculations and the conditions which were anticipated in the design with regard to the maximum credible accident.
- The ability of the shipping container to meet the conditions postulated for its use including accident conditions and any information on tests of prototypes.
- Operating and handling instructions for the use of the shipping container, together with recommendations for initial and subsequent periodic service testing and inspection of the shipping container.

16.2.1.2. Upon approval, the competent authority of the country in which the shipment originates shall issue an approval identification for the type of shipping container. This approval identification, together with a serial number (where such is provided), shall be stamped, embossed or otherwise permanently applied to the container in a prominent location.

16.2.2. Size of packages: loading equipment
Packages must be of such size that they can be loaded and unloaded with the equipment available at scheduled transfer points.

* Refer to section 5.
16.2.3. **Limitation of external dose-rate**

16.2.3.1. Shipments of large sources will be divided into category "white" and category "yellow" packages and, except as provided in this section, shall meet the limits for external radiation set forth in section 7 and the contamination limits of section 11.

16.2.3.2. When transported in accordance with the conditions set forth in (a), (b), (c) and (d) below, a package which contains a large radioactive source shall be considered as a category yellow package and shall be exempted from the limits on the number of radiation units set forth in paragraph 10.2.2.

(a) The dose-rate of radiation originating from the radioactive material or from any part of the aggregate constituting the complete package, at all times during transport, shall not exceed:

(i) At any point of readily accessible, external surface of the shipping container:

200 mr/h for X- and/or gamma-radiation  
The equivalent of 200 mr/h for beta-radiation  
Those values of flux given in Table II, Annex I, for neutrons.

(ii) At 3 m from the accessible, external surface of the shipping container:

10 mr/h for X- and/or gamma-radiation  
The equivalent of 10 mr/h for beta-radiation  
Those values of flux given in Table III, Annex I, for neutrons.

The limits for dose rates referred to in this sub-paragraph 16.2.3.2. are considered to be equivalent in biological effectiveness for each type of radiation; therefore, if more than one of these types of radiation are present, the total radiation shall not exceed the equivalent of one of the above-limits.

(b) **Rail or road:** The radioactive materials must be shipped in full truck- or car-load lots.

**Water:** For separation required for carriage on board ships, the table of complementary data in Table VI, Annex I, shall be used where the number of units is taken as the radiation level in mr/h (or equivalent) at a distance of 1 m from the surface of the package.

**Air:** Shipments by air shall be made only under special arrangement in accordance with the provisions of section 17.
(c) The shipment is loaded and unloaded by or under the direct supervision of the consignee or the consignor.

(d) The vehicle is labelled or marked in accordance with the provisions of sub-section 8.2.

16.2.3.3. Shipments of large radioactive sources which do not meet the external radiation limits of section 7 or the provisions of sub-paragraph 16.2.3.2. above shall be transported only by special arrangement under the provisions of section 17.

16.2.4. **Heat transfer**

16.2.4.1. All shipments of large radioactive sources shall be so packaged that the heat generated within the package due to the presence of the radioactive materials will not, at any time during transport, affect the efficiency of the container under the conditions encountered in transport. Particular attention shall be paid to the effects of heat which may:

(a) Alter the form or nature of the source or, if the material is enclosed in an intimate receptacle, cause the receptacle or the material to melt (see paragraph 16.2.5. and subsection 15.3); or

(b) Cause loss of efficiency of the package by melting of the shielding or cracking of the container due to thermal stresses.

16.2.4.2. The package shall be so designed and constructed that the temperature of the external accessible surfaces of the container (or surrounding screen, if used) shall not, at any time during transport, exceed $82^\circ \text{C} (180^\circ \text{F})$.

16.2.4.3. Before shipment of a large radioactive source, the loaded container shall be held by the consignor until the temperature of the system has reached equilibrium, unless it has been demonstrated to the satisfaction of the carrier that its equilibrium conditions satisfy the requirements of this section.

16.2.4.4. If a coolant or cooling system is provided, it shall meet the following conditions:

(a) The primary gas or liquid coolant (i.e. coolant which comes in contact with the radiation source) shall not be circulated outside of the shielding of the container.

(b) If a mechanical cooling-system is provided, failure of the mechanism shall not result in an excessive pressure increase or a significant radiation hazard.
When a liquid coolant is used, provisions shall be made to prevent freezing in transit, or suitable ullage (outage) or other means shall be provided to prevent damage to the container or its contents due to freezing.

If a liquid coolant is used and temperatures inside the container may reach the boiling point of the coolant at any time during transport, the container shall be designed and constructed to withstand the internal pressures developed without loss of coolant, container efficiency or release of radioactive materials. If the container is not designed to meet the above requirement, the system shall be designed to restrict the liquid temperatures inside the container and in the vicinity of the radioactive materials to at least 10°C (20°F) below the boiling point of the liquid at the highest point of the route. Where pressure-release devices are used, the provision of means to prevent the release of particulate matter shall be considered.

16.2.5. Irradiated nuclear fuel

Irradiated nuclear fuel should be stored at the point at which the shipment is to originate for a period of time which will ensure that, when the shipping container is loaded with the fuel elements, the maximum temperature of any fuel element will remain such that all parts of the fuel, cladding, container or built-in neutron absorber will remain at least 100°C (180°F) below their respective melting points. For this evaluation, no heat-transfer media shall be assumed to be present other than air convection for a dry loaded container and other than static water (internal) and air convection (external) for a wet loaded container.

16.3. SHIPPING PROCEDURES

The shipping procedures to be used for the transport of large radioactive sources shall be approved by the competent authority of the country in which the shipment originates.

16.3.1. Requests for approval

Requests for approval shall be made to the competent authority of the country in which the shipment originates. Requests for approval shall include the following information:

The route to be followed;

The mode of transport to be employed;
Any special precaution to be taken en route or in case of accident or unexpected delay;

The type, form and maximum quantity of the radioactive materials to be carried in each shipping container and the type and approval identification of each container to be used.

16.3.2. Certification
Upon approval, the authority shall issue a certificate stating that the shipment is in all respects in accordance with these Regulations and is allowed for the mode of transport to be used. Where necessary, the certificate shall include a list of the conditions under which the shipment is to be made, such as routing, transfer points, final destination and any special precautions to be followed.

16.3.3. Notification
Before the shipment takes place, a copy of the certificate shall be issued to the competent authority of each country through or into which the shipment is to pass.

16.3.4. Arrangements with carriers
Prior arrangements shall be made with each carrier who is to transport any shipment involving a large radioactive source.

17. SPECIAL ARRANGEMENTS

17.1. Application for special arrangements referred to in these Regulations shall be made by the consignor to the competent authority of the country in which the shipment originates and the competent authority of each country through or into which the shipment is to pass.

17.2. In any provision for a shipment by a special arrangement, the following factors shall be taken into account:

17.2.1. Any particular design features of the shipping container, having regard to the special purpose for which it is to be used.

17.2.2. The special precautions to be taken en route or in case of accident or unexpected delay.

17.2.3. Any special loading, unloading and other handling procedures.

17.3. Each competent authority shall consider the application and, taking into account the frequency of radioactive shipments and the reasonable likelihood of exposure, determine whether the
shipment as proposed ensures that no person would be exposed to greater than the applicable permissible limits. Among the conditions which may be specified in the approval by a competent authority are routing, including all anticipated transfer-points and final destination, and special precautions to be followed en route or in case of accident or unusual delay.

17.4. Shipments under special arrangements shall not be made until approval has been obtained from each competent authority involved.
# ANNEX I

## Table I

**NEUTRON FLUXES BIOLOGICALLY EQUIVALENT TO A DOSE-RATE OF 10 mr/24 h OF GAMMA-RADIATION**

<table>
<thead>
<tr>
<th>Energy of neutrons</th>
<th>Flux: Neutrons/cm²s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.025 eV</td>
<td>111</td>
</tr>
<tr>
<td>10 eV</td>
<td>111</td>
</tr>
<tr>
<td>10 keV</td>
<td>56</td>
</tr>
<tr>
<td>0.1 MeV</td>
<td>11</td>
</tr>
<tr>
<td>0.5 MeV</td>
<td>4</td>
</tr>
<tr>
<td>1 MeV</td>
<td>3</td>
</tr>
<tr>
<td>2 MeV</td>
<td>2</td>
</tr>
<tr>
<td>3 to 10 MeV</td>
<td>2</td>
</tr>
</tbody>
</table>

## Table II

**NEUTRON FLUXES BIOLOGICALLY EQUIVALENT TO A DOSE-RATE OF 200 mr/h OF GAMMA-RADIATION**

<table>
<thead>
<tr>
<th>Energy of neutrons</th>
<th>Flux: Neutrons/cm²s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.025 eV</td>
<td>53 300</td>
</tr>
<tr>
<td>10 eV</td>
<td>53 300</td>
</tr>
<tr>
<td>10 keV</td>
<td>26 700</td>
</tr>
<tr>
<td>0.1 MeV</td>
<td>5 330</td>
</tr>
<tr>
<td>0.5 MeV</td>
<td>2 130</td>
</tr>
<tr>
<td>1 MeV</td>
<td>1 600</td>
</tr>
<tr>
<td>2 MeV</td>
<td>1 070</td>
</tr>
<tr>
<td>3 to 10 MeV</td>
<td>800</td>
</tr>
</tbody>
</table>

## Table III

**NEUTRON FLUXES BIOLOGICALLY EQUIVALENT TO A DOSE-RATE OF 10 mr/h OF GAMMA-RADIATION**

<table>
<thead>
<tr>
<th>Energy of neutrons</th>
<th>Flux: Neutrons/cm²s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.025 eV</td>
<td>2 670</td>
</tr>
<tr>
<td>10 eV</td>
<td>2 670</td>
</tr>
<tr>
<td>10 keV</td>
<td>1 330</td>
</tr>
<tr>
<td>0.1 MeV</td>
<td>270</td>
</tr>
<tr>
<td>0.5 MeV</td>
<td>110</td>
</tr>
<tr>
<td>1 MeV</td>
<td>80</td>
</tr>
<tr>
<td>2 MeV</td>
<td>53</td>
</tr>
<tr>
<td>3 to 10 MeV</td>
<td>40</td>
</tr>
<tr>
<td>Nuclide</td>
<td>Atomic number</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Actinium-227</td>
<td>89</td>
</tr>
<tr>
<td>Actinium-228</td>
<td>89</td>
</tr>
<tr>
<td>Americium-241</td>
<td>95</td>
</tr>
<tr>
<td>Americium-243</td>
<td>95</td>
</tr>
<tr>
<td>Antimony-122</td>
<td>51</td>
</tr>
<tr>
<td>Antimony-124</td>
<td>51</td>
</tr>
<tr>
<td>Antimony-125</td>
<td>51</td>
</tr>
<tr>
<td>Argon-37</td>
<td>18</td>
</tr>
<tr>
<td>Argon-41</td>
<td>18</td>
</tr>
<tr>
<td>Arsenic-73</td>
<td>33</td>
</tr>
<tr>
<td>Arsenic-74</td>
<td>33</td>
</tr>
<tr>
<td>Arsenic-76</td>
<td>33</td>
</tr>
<tr>
<td>Arsenic-77</td>
<td>33</td>
</tr>
<tr>
<td>Astatine-211</td>
<td>85</td>
</tr>
<tr>
<td>Barium-131</td>
<td>56</td>
</tr>
<tr>
<td>Berkelium-249</td>
<td>97</td>
</tr>
<tr>
<td>Beryllium-7</td>
<td>4</td>
</tr>
<tr>
<td>Bismuth-206</td>
<td>83</td>
</tr>
<tr>
<td>Bismuth-207</td>
<td>83</td>
</tr>
<tr>
<td>Bismuth-210</td>
<td>83</td>
</tr>
<tr>
<td>Bismuth-212</td>
<td>83</td>
</tr>
<tr>
<td>Bromine-82</td>
<td>35</td>
</tr>
<tr>
<td>Cadmium-109</td>
<td>48</td>
</tr>
<tr>
<td>Cadmium-115</td>
<td>48</td>
</tr>
<tr>
<td>Cadmium-115m</td>
<td>48</td>
</tr>
<tr>
<td>Cerium-131</td>
<td>55</td>
</tr>
<tr>
<td>Cerium-134m</td>
<td>55</td>
</tr>
<tr>
<td>Caesium-131</td>
<td>55</td>
</tr>
<tr>
<td>Caesium-134</td>
<td>55</td>
</tr>
<tr>
<td>Caesium-135</td>
<td>55</td>
</tr>
<tr>
<td>Caesium-136</td>
<td>55</td>
</tr>
<tr>
<td>Caesium-137</td>
<td>55</td>
</tr>
<tr>
<td>Calcium-45</td>
<td>20</td>
</tr>
<tr>
<td>Calcium-47</td>
<td>20</td>
</tr>
<tr>
<td>Californium-249</td>
<td>98</td>
</tr>
<tr>
<td>Californium-250</td>
<td>98</td>
</tr>
<tr>
<td>Californium-252</td>
<td>98</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>6</td>
</tr>
<tr>
<td>Cerium-141</td>
<td>58</td>
</tr>
<tr>
<td>Cerium-143</td>
<td>58</td>
</tr>
<tr>
<td>Cerium-144</td>
<td>58</td>
</tr>
<tr>
<td>Chlorine-36</td>
<td>17</td>
</tr>
<tr>
<td>Chlorine-38</td>
<td>17</td>
</tr>
</tbody>
</table>

* See "The classification of radioisotopes for packaging" in No. 7 of this Series.
** Although this form is still in wide use, the International Union of Pure and Applied Chemistry recommends "Ar".

This publication is no longer valid
Please see http://www-ns.iaea.org/standards/
<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Atomic number</th>
<th>Symbol</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium-51</td>
<td>24</td>
<td>Cr$^{51}$</td>
<td>III</td>
</tr>
<tr>
<td>Cobalt-57</td>
<td>27</td>
<td>Co$^{57}$</td>
<td>III</td>
</tr>
<tr>
<td>Cobalt-58m</td>
<td>27</td>
<td>Co$^{58}$m</td>
<td>III</td>
</tr>
<tr>
<td>Cobalt-58</td>
<td>27</td>
<td>Co$^{58}$</td>
<td>III</td>
</tr>
<tr>
<td>Cobalt-60</td>
<td>27</td>
<td>Co$^{60}$</td>
<td>III</td>
</tr>
<tr>
<td>Copper-64</td>
<td>29</td>
<td>Cu$^{64}$</td>
<td>III</td>
</tr>
<tr>
<td>Curium-242</td>
<td>96</td>
<td>Cm$^{242}$</td>
<td>II</td>
</tr>
<tr>
<td>Curium-243</td>
<td>96</td>
<td>Cm$^{243}$</td>
<td>I</td>
</tr>
<tr>
<td>Curium-244</td>
<td>96</td>
<td>Cm$^{244}$</td>
<td>I</td>
</tr>
<tr>
<td>Curium-245</td>
<td>96</td>
<td>Cm$^{245}$</td>
<td>I</td>
</tr>
<tr>
<td>Curium-246</td>
<td>96</td>
<td>Cm$^{246}$</td>
<td>I</td>
</tr>
<tr>
<td>Dysprosium-165</td>
<td>66</td>
<td>Dy$^{165}$</td>
<td>III</td>
</tr>
<tr>
<td>Erbium-169</td>
<td>68</td>
<td>Er$^{169}$</td>
<td>III</td>
</tr>
<tr>
<td>Erbium-171</td>
<td>68</td>
<td>Er$^{171}$</td>
<td>III</td>
</tr>
<tr>
<td>Europium-152 (9.2 h)</td>
<td>63</td>
<td>Eu$^{152}$</td>
<td>III</td>
</tr>
<tr>
<td>Europium-152 (13 yr)</td>
<td>63</td>
<td>Eu$^{152}$</td>
<td>III</td>
</tr>
<tr>
<td>Europium-154</td>
<td>63</td>
<td>Eu$^{154}$</td>
<td>II</td>
</tr>
<tr>
<td>Europium-155</td>
<td>63</td>
<td>Eu$^{155}$</td>
<td>III</td>
</tr>
<tr>
<td>Fluorine-18</td>
<td>9</td>
<td>F$^{18}$</td>
<td>III</td>
</tr>
<tr>
<td>Gadolinium-153</td>
<td>64</td>
<td>Gd$^{153}$</td>
<td>III</td>
</tr>
<tr>
<td>Gadolinium-159</td>
<td>64</td>
<td>Gd$^{159}$</td>
<td>III</td>
</tr>
<tr>
<td>Gallium-72</td>
<td>31</td>
<td>Ga$^{72}$</td>
<td>III</td>
</tr>
<tr>
<td>Germanium-71</td>
<td>32</td>
<td>Ge$^{71}$</td>
<td>III</td>
</tr>
<tr>
<td>Gold-196</td>
<td>79</td>
<td>Au$^{196}$</td>
<td>III</td>
</tr>
<tr>
<td>Gold-198</td>
<td>79</td>
<td>Au$^{198}$</td>
<td>III</td>
</tr>
<tr>
<td>Gold-199</td>
<td>79</td>
<td>Au$^{199}$</td>
<td>III</td>
</tr>
<tr>
<td>Hafnium-181</td>
<td>72</td>
<td>Hf$^{181}$</td>
<td>III</td>
</tr>
<tr>
<td>Holmium-166</td>
<td>67</td>
<td>Ho$^{166}$</td>
<td>III</td>
</tr>
<tr>
<td>Hydrogen-3</td>
<td>1</td>
<td>H$^3$</td>
<td>III</td>
</tr>
<tr>
<td>Indium-113m</td>
<td>49</td>
<td>In$^{113}$m</td>
<td>III</td>
</tr>
<tr>
<td>Indium-114m</td>
<td>49</td>
<td>In$^{114}$m</td>
<td>III</td>
</tr>
<tr>
<td>Indium-115m</td>
<td>49</td>
<td>In$^{115}$m</td>
<td>III</td>
</tr>
<tr>
<td>Indium-115*</td>
<td>49</td>
<td>In$^{115}$</td>
<td>III</td>
</tr>
<tr>
<td>Iodine-126</td>
<td>53</td>
<td>I$^{126}$</td>
<td>III</td>
</tr>
<tr>
<td>Iodine-129</td>
<td>53</td>
<td>I$^{129}$</td>
<td>III</td>
</tr>
<tr>
<td>Iodine-131</td>
<td>53</td>
<td>I$^{131}$</td>
<td>III</td>
</tr>
<tr>
<td>Iodine-132</td>
<td>53</td>
<td>I$^{132}$</td>
<td>III</td>
</tr>
<tr>
<td>Iodine-133</td>
<td>53</td>
<td>I$^{133}$</td>
<td>III</td>
</tr>
<tr>
<td>Iodine-134</td>
<td>53</td>
<td>I$^{134}$</td>
<td>III</td>
</tr>
<tr>
<td>Iodine-135</td>
<td>53</td>
<td>I$^{135}$</td>
<td>III</td>
</tr>
<tr>
<td>Iridium-190</td>
<td>77</td>
<td>Ir$^{190}$</td>
<td>III</td>
</tr>
<tr>
<td>Iridium-192</td>
<td>77</td>
<td>Ir$^{192}$</td>
<td>III</td>
</tr>
<tr>
<td>Iridium-194</td>
<td>77</td>
<td>Ir$^{194}$</td>
<td>III</td>
</tr>
<tr>
<td>Iron-55</td>
<td>26</td>
<td>Fe$^{55}$</td>
<td>III</td>
</tr>
<tr>
<td>Iron-59</td>
<td>26</td>
<td>Fe$^{59}$</td>
<td>III</td>
</tr>
</tbody>
</table>

* This nuclide has a specific activity of less than 0.002 μCi/g (see 1.1.6.).
<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Atomic number</th>
<th>Symbol</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krypton-85m</td>
<td>36</td>
<td>Kr$_{85}^m$</td>
<td>III</td>
</tr>
<tr>
<td>Krypton-85</td>
<td>36</td>
<td>Kr$_{85}$</td>
<td>III</td>
</tr>
<tr>
<td>Krypton-87</td>
<td>36</td>
<td>Kr$_{87}$</td>
<td>III</td>
</tr>
<tr>
<td>Lanthanum-140</td>
<td>57</td>
<td>La$_{140}$</td>
<td>III</td>
</tr>
<tr>
<td>Lead-203</td>
<td>82</td>
<td>Pb$_{203}$</td>
<td>III</td>
</tr>
<tr>
<td>Lead-210</td>
<td>82</td>
<td>Pb$_{210}$</td>
<td>II</td>
</tr>
<tr>
<td>Lead-212</td>
<td>82</td>
<td>Pb$_{212}$</td>
<td>III</td>
</tr>
<tr>
<td>Lutecium-177</td>
<td>71</td>
<td>Lu$_{177}$</td>
<td>III</td>
</tr>
<tr>
<td>Manganese-52</td>
<td>25</td>
<td>Mn$_{52}$</td>
<td>III</td>
</tr>
<tr>
<td>Manganese-54</td>
<td>25</td>
<td>Mn$_{54}$</td>
<td>III</td>
</tr>
<tr>
<td>Manganese-56</td>
<td>25</td>
<td>Mn$_{56}$</td>
<td>III</td>
</tr>
<tr>
<td>Mercury-197m</td>
<td>80</td>
<td>Hg$_{197}^m$</td>
<td>III</td>
</tr>
<tr>
<td>Mercury-197</td>
<td>80</td>
<td>Hg$_{197}$</td>
<td>III</td>
</tr>
<tr>
<td>Mercury-203</td>
<td>80</td>
<td>Hg$_{203}$</td>
<td>III</td>
</tr>
<tr>
<td>Molybdenum-99</td>
<td>42</td>
<td>Mo$_{99}$</td>
<td>III</td>
</tr>
<tr>
<td>Neodymium-144*</td>
<td>60</td>
<td>Nd$_{144}$</td>
<td>III</td>
</tr>
<tr>
<td>Neodymium-147</td>
<td>60</td>
<td>Nd$_{147}$</td>
<td>III</td>
</tr>
<tr>
<td>Neodymium-149</td>
<td>60</td>
<td>Nd$_{149}$</td>
<td>III</td>
</tr>
<tr>
<td>Neptunium-237</td>
<td>93</td>
<td>Np$_{237}$</td>
<td>I</td>
</tr>
<tr>
<td>Neptunium-239</td>
<td>93</td>
<td>Np$_{239}$</td>
<td>III</td>
</tr>
<tr>
<td>Nickel-59</td>
<td>28</td>
<td>Ni$_{59}$</td>
<td>III</td>
</tr>
<tr>
<td>Nickel-63</td>
<td>28</td>
<td>Ni$_{63}$</td>
<td>III</td>
</tr>
<tr>
<td>Nickel-65</td>
<td>28</td>
<td>Ni$_{65}$</td>
<td>III</td>
</tr>
<tr>
<td>Niobium-93m</td>
<td>41</td>
<td>Nb$_{93}^m$</td>
<td>III</td>
</tr>
<tr>
<td>Niobium-95</td>
<td>41</td>
<td>Nb$_{95}$</td>
<td>III</td>
</tr>
<tr>
<td>Niobium-97</td>
<td>41</td>
<td>Nb$_{97}$</td>
<td>III</td>
</tr>
<tr>
<td>Osmium-185</td>
<td>76</td>
<td>Os$_{185}$</td>
<td>III</td>
</tr>
<tr>
<td>Osmium-191m</td>
<td>75</td>
<td>Os$_{191}^m$</td>
<td>III</td>
</tr>
<tr>
<td>Osmium-191</td>
<td>75</td>
<td>Os$_{191}$</td>
<td>III</td>
</tr>
<tr>
<td>Osmium-193</td>
<td>75</td>
<td>Os$_{193}$</td>
<td>III</td>
</tr>
<tr>
<td>Palladium-103</td>
<td>46</td>
<td>Pd$_{103}$</td>
<td>III</td>
</tr>
<tr>
<td>Palladium-109</td>
<td>46</td>
<td>Pd$_{109}$</td>
<td>III</td>
</tr>
<tr>
<td>Phosphorus-32</td>
<td>15</td>
<td>P$_{32}$</td>
<td>III</td>
</tr>
<tr>
<td>Platinum-191</td>
<td>78</td>
<td>Pt$_{191}$</td>
<td>III</td>
</tr>
<tr>
<td>Platinum-193m</td>
<td>78</td>
<td>Pt$_{193}^m$</td>
<td>III</td>
</tr>
<tr>
<td>Platinum-197m</td>
<td>78</td>
<td>Pt$_{197}^m$</td>
<td>III</td>
</tr>
<tr>
<td>Platinum-197</td>
<td>78</td>
<td>Pt$_{197}$</td>
<td>III</td>
</tr>
<tr>
<td>Plutonium-238</td>
<td>94</td>
<td>Pu$_{238}$</td>
<td>I</td>
</tr>
<tr>
<td>Plutonium-239</td>
<td>94</td>
<td>Pu$_{239}$</td>
<td>I</td>
</tr>
<tr>
<td>Plutonium-240</td>
<td>94</td>
<td>Pu$_{240}$</td>
<td>I</td>
</tr>
<tr>
<td>Plutonium-241</td>
<td>94</td>
<td>Pu$_{241}$</td>
<td>II</td>
</tr>
<tr>
<td>Plutonium-242</td>
<td>94</td>
<td>Pu$_{242}$</td>
<td>I</td>
</tr>
<tr>
<td>Polonium-210</td>
<td>84</td>
<td>Po$_{210}$</td>
<td>II</td>
</tr>
<tr>
<td>Potassium-42</td>
<td>19</td>
<td>K$_{42}$</td>
<td>III</td>
</tr>
<tr>
<td>Praseodymium-142</td>
<td>59</td>
<td>Pr$_{142}$</td>
<td>III</td>
</tr>
<tr>
<td>Praseodymium-143</td>
<td>59</td>
<td>Pr$_{143}$</td>
<td>III</td>
</tr>
</tbody>
</table>

* This nuclide has a specific activity of less than 0.002 μe/g (see 1.1.6.).
<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Atomic number</th>
<th>Symbol</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promethium-147</td>
<td>61</td>
<td>Pm$^{147}$</td>
<td>III</td>
</tr>
<tr>
<td>Promethium-149</td>
<td>61</td>
<td>Pm$^{149}$</td>
<td>III</td>
</tr>
<tr>
<td>Protactinium-230</td>
<td>91</td>
<td>Pa$^{230}$</td>
<td>II</td>
</tr>
<tr>
<td>Protactinium-231</td>
<td>91</td>
<td>Pa$^{231}$</td>
<td>I</td>
</tr>
<tr>
<td>Protactinium-233</td>
<td>91</td>
<td>Pa$^{233}$</td>
<td>III</td>
</tr>
<tr>
<td>Radium-223</td>
<td>88</td>
<td>Ra$^{223}$</td>
<td>II</td>
</tr>
<tr>
<td>Radium-224</td>
<td>88</td>
<td>Ra$^{224}$</td>
<td>II</td>
</tr>
<tr>
<td>Radium-226</td>
<td>88</td>
<td>Ra$^{226}$</td>
<td>I</td>
</tr>
<tr>
<td>Radium-228</td>
<td>88</td>
<td>Ra$^{228}$</td>
<td>II</td>
</tr>
<tr>
<td>Radon-220</td>
<td>86</td>
<td>Rn$^{220}$</td>
<td>III</td>
</tr>
<tr>
<td>Radon-222</td>
<td>86</td>
<td>Rn$^{222}$</td>
<td>II</td>
</tr>
<tr>
<td>Rhenium-183</td>
<td>75</td>
<td>Re$^{183}$</td>
<td>III</td>
</tr>
<tr>
<td>Rhenium-186</td>
<td>75</td>
<td>Re$^{186}$</td>
<td>III</td>
</tr>
<tr>
<td>Rhenium-187</td>
<td>75</td>
<td>Re$^{187}$</td>
<td>III</td>
</tr>
<tr>
<td>Rhenium-188</td>
<td>75</td>
<td>Re$^{188}$</td>
<td>III</td>
</tr>
<tr>
<td>Rhenium-natural</td>
<td>75</td>
<td>Rn</td>
<td>III</td>
</tr>
<tr>
<td>Rhodium-103</td>
<td>45</td>
<td>Rh$^{103}$</td>
<td>III</td>
</tr>
<tr>
<td>Rhodium-105</td>
<td>45</td>
<td>Rh$^{105}$</td>
<td>III</td>
</tr>
<tr>
<td>Rubidium-86</td>
<td>37</td>
<td>Rb$^{86}$</td>
<td>III</td>
</tr>
<tr>
<td>Rubidium-87</td>
<td>37</td>
<td>Rb$^{87}$</td>
<td>III</td>
</tr>
<tr>
<td>Ruthenium-97</td>
<td>44</td>
<td>Ru$^{97}$</td>
<td>III</td>
</tr>
<tr>
<td>Ruthenium-103</td>
<td>44</td>
<td>Ru$^{103}$</td>
<td>III</td>
</tr>
<tr>
<td>Ruthenium-105</td>
<td>44</td>
<td>Ru$^{105}$</td>
<td>III</td>
</tr>
<tr>
<td>Ruthenium-106</td>
<td>44</td>
<td>Ru$^{106}$</td>
<td>III</td>
</tr>
<tr>
<td>Samarium-147</td>
<td>62</td>
<td>Sm$^{147}$</td>
<td>III</td>
</tr>
<tr>
<td>Samarium-151</td>
<td>62</td>
<td>Sm$^{151}$</td>
<td>III</td>
</tr>
<tr>
<td>Samarium-153</td>
<td>62</td>
<td>Sm$^{153}$</td>
<td>III</td>
</tr>
<tr>
<td>Scandium-46</td>
<td>21</td>
<td>Sc$^{46}$</td>
<td>III</td>
</tr>
<tr>
<td>Scandium-47</td>
<td>21</td>
<td>Sc$^{47}$</td>
<td>III</td>
</tr>
<tr>
<td>Scandium-48</td>
<td>21</td>
<td>Sc$^{48}$</td>
<td>III</td>
</tr>
<tr>
<td>Selenium-75</td>
<td>34</td>
<td>Se$^{75}$</td>
<td>III</td>
</tr>
<tr>
<td>Silicon-31</td>
<td>14</td>
<td>Si$^{31}$</td>
<td>III</td>
</tr>
<tr>
<td>Silver-105</td>
<td>47</td>
<td>Ag$^{105}$</td>
<td>III</td>
</tr>
<tr>
<td>Silver-110</td>
<td>47</td>
<td>Ag$^{110}$</td>
<td>III</td>
</tr>
<tr>
<td>Silver-111</td>
<td>47</td>
<td>Ag$^{111}$</td>
<td>III</td>
</tr>
<tr>
<td>Sodium-22</td>
<td>11</td>
<td>Na$^{22}$</td>
<td>III</td>
</tr>
<tr>
<td>Sodium-24</td>
<td>11</td>
<td>Na$^{24}$</td>
<td>III</td>
</tr>
<tr>
<td>Strontium-85</td>
<td>38</td>
<td>Sr$^{85}$</td>
<td>III</td>
</tr>
<tr>
<td>Strontium-85m</td>
<td>38</td>
<td>Sr$^{85}$</td>
<td>III</td>
</tr>
<tr>
<td>Strontium-89</td>
<td>38</td>
<td>Sr$^{89}$</td>
<td>III</td>
</tr>
<tr>
<td>Strontium-90</td>
<td>38</td>
<td>Sr$^{90}$</td>
<td>II</td>
</tr>
<tr>
<td>Strontium-91</td>
<td>38</td>
<td>Sr$^{91}$</td>
<td>III</td>
</tr>
<tr>
<td>Strontium-92</td>
<td>38</td>
<td>Sr$^{92}$</td>
<td>III</td>
</tr>
<tr>
<td>Sulphur-35</td>
<td>16</td>
<td>S$^{35}$</td>
<td>III</td>
</tr>
<tr>
<td>Tantalum-182</td>
<td>73</td>
<td>Ta$^{182}$</td>
<td>III</td>
</tr>
<tr>
<td>Technetium-96</td>
<td>43</td>
<td>Tc$^{96}$</td>
<td>III</td>
</tr>
<tr>
<td>Technetium-96m</td>
<td>43</td>
<td>Tc$^{96m}$</td>
<td>III</td>
</tr>
<tr>
<td>Nuclide</td>
<td>Atomic number</td>
<td>Symbol</td>
<td>Group</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------</td>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>Technetium-97m</td>
<td>43</td>
<td>Tc₉₇m</td>
<td>III</td>
</tr>
<tr>
<td>Technetium-97</td>
<td>43</td>
<td>Tc₉₇</td>
<td>III</td>
</tr>
<tr>
<td>Technetium-99m</td>
<td>43</td>
<td>Tc₉₉m</td>
<td>III</td>
</tr>
<tr>
<td>Technetium-99</td>
<td>43</td>
<td>Tc₉₉</td>
<td>III</td>
</tr>
<tr>
<td>Tellurium-125m</td>
<td>52</td>
<td>Te₁₂₅m</td>
<td>III</td>
</tr>
<tr>
<td>Tellurium-127m</td>
<td>52</td>
<td>Te₁₂₇m</td>
<td>III</td>
</tr>
<tr>
<td>Tellurium-127</td>
<td>52</td>
<td>Te₁₂₇</td>
<td>III</td>
</tr>
<tr>
<td>Tellurium-129m</td>
<td>52</td>
<td>Te₁₂₉m</td>
<td>III</td>
</tr>
<tr>
<td>Tellurium-129</td>
<td>52</td>
<td>Te₁₂₉</td>
<td>III</td>
</tr>
<tr>
<td>Tellurium-131m</td>
<td>52</td>
<td>Te₁₃₁m</td>
<td>III</td>
</tr>
<tr>
<td>Tellurium-132</td>
<td>52</td>
<td>Te₁₃₂</td>
<td>III</td>
</tr>
<tr>
<td>Terbium-160</td>
<td>65</td>
<td>Tb₁₆₀</td>
<td>III</td>
</tr>
<tr>
<td>Thallium-200</td>
<td>81</td>
<td>Tl₂₀₀</td>
<td>III</td>
</tr>
<tr>
<td>Thallium-201</td>
<td>81</td>
<td>Tl₂₀₁</td>
<td>III</td>
</tr>
<tr>
<td>Thallium-202</td>
<td>81</td>
<td>Tl₂₀₂</td>
<td>III</td>
</tr>
<tr>
<td>Thallium-204</td>
<td>81</td>
<td>Tl₂₀₄</td>
<td>III</td>
</tr>
<tr>
<td>Thorium-227</td>
<td>90</td>
<td>Th₂₂₇</td>
<td>I</td>
</tr>
<tr>
<td>Thorium-228</td>
<td>90</td>
<td>Th₂₂₈</td>
<td>I</td>
</tr>
<tr>
<td>Thorium-230</td>
<td>90</td>
<td>Th₂₃₀</td>
<td>I</td>
</tr>
<tr>
<td>Thorium-231</td>
<td>90</td>
<td>Th₂₃₁</td>
<td>III</td>
</tr>
<tr>
<td>Thorium-232</td>
<td>90</td>
<td>Th₂₃₂</td>
<td>III</td>
</tr>
<tr>
<td>Thorium-234</td>
<td>90</td>
<td>Th₂₃₄</td>
<td>III</td>
</tr>
<tr>
<td>Thorium, natural</td>
<td>90</td>
<td>Th</td>
<td>III</td>
</tr>
<tr>
<td>Thulium-170</td>
<td>69</td>
<td>Tm₁₇₀</td>
<td>III</td>
</tr>
<tr>
<td>Thulium-171</td>
<td>69</td>
<td>Tm₁₇₁</td>
<td>III</td>
</tr>
<tr>
<td>Tin-113</td>
<td>50</td>
<td>Sn₁₁₃</td>
<td>III</td>
</tr>
<tr>
<td>Tin-125</td>
<td>50</td>
<td>Sn₁₂₅</td>
<td>III</td>
</tr>
<tr>
<td>Tungsten-181</td>
<td>74</td>
<td>W₁₈₁</td>
<td>III</td>
</tr>
<tr>
<td>Tungsten-185</td>
<td>74</td>
<td>W₁₈₅</td>
<td>III</td>
</tr>
<tr>
<td>Tungsten-187</td>
<td>74</td>
<td>W₁₈₇</td>
<td>III</td>
</tr>
<tr>
<td>Uranium-230</td>
<td>92</td>
<td>U₂₃₀</td>
<td>II</td>
</tr>
<tr>
<td>Uranium-232</td>
<td>92</td>
<td>U₂₃₂</td>
<td>II</td>
</tr>
<tr>
<td>Uranium-233</td>
<td>92</td>
<td>U₂₃₃</td>
<td>II</td>
</tr>
<tr>
<td>Uranium-234</td>
<td>92</td>
<td>U₂₃₄</td>
<td>II†</td>
</tr>
<tr>
<td>Uranium-235</td>
<td>92</td>
<td>U₂₃₅</td>
<td>III</td>
</tr>
<tr>
<td>Uranium-236</td>
<td>92</td>
<td>U₂₃₆</td>
<td>II</td>
</tr>
<tr>
<td>Uranium-238</td>
<td>92</td>
<td>U₂₃₈</td>
<td>III</td>
</tr>
<tr>
<td>Uranium, natural</td>
<td>92</td>
<td>U</td>
<td>III</td>
</tr>
<tr>
<td>Vanadium-48</td>
<td>23</td>
<td>V₄₈</td>
<td>III</td>
</tr>
<tr>
<td>Xenon-131m</td>
<td>54</td>
<td>Xe₁₃₁m</td>
<td>III</td>
</tr>
<tr>
<td>Xenon-133</td>
<td>54</td>
<td>Xe₁₃₃</td>
<td>III</td>
</tr>
<tr>
<td>Xenon-135</td>
<td>54</td>
<td>Xe₁₃₅</td>
<td>III</td>
</tr>
<tr>
<td>Ytterbium-175</td>
<td>79</td>
<td>Yb₁₇₅</td>
<td>III</td>
</tr>
<tr>
<td>Yttrium-90</td>
<td>39</td>
<td>Y₉₀</td>
<td>III</td>
</tr>
<tr>
<td>Yttrium-91m</td>
<td>39</td>
<td>Y₉₁m</td>
<td>III</td>
</tr>
<tr>
<td>Yttrium-91</td>
<td>39</td>
<td>Y₉₁</td>
<td>III</td>
</tr>
</tbody>
</table>

† Uranium enriched in U²₃⁵ and containing U²₃⁴ is in Group III.
<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Atomic number</th>
<th>Symbol</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yttrium-92</td>
<td>39</td>
<td>Y\textsuperscript{92}</td>
<td>III</td>
</tr>
<tr>
<td>Yttrium-93</td>
<td>39</td>
<td>Y\textsuperscript{93}</td>
<td>III</td>
</tr>
<tr>
<td>Zinc-65</td>
<td>30</td>
<td>Zn\textsuperscript{65}</td>
<td>III</td>
</tr>
<tr>
<td>Zinc-69\textsubscript{m}</td>
<td>30</td>
<td>Zn\textsuperscript{69}\textsubscript{m}</td>
<td>III</td>
</tr>
<tr>
<td>Zirconium-93</td>
<td>40</td>
<td>Zr\textsuperscript{93}</td>
<td>III</td>
</tr>
<tr>
<td>Zirconium-95</td>
<td>40</td>
<td>Zr\textsuperscript{95}</td>
<td>III</td>
</tr>
<tr>
<td>Zirconium-97</td>
<td>40</td>
<td>Zr\textsuperscript{97}</td>
<td>III</td>
</tr>
</tbody>
</table>

**Table V**

**SAFE DISTANCES FOR UNDEVELOPED FILMS OR PLATES**

*Mixed loading or storage of undeveloped films or plates with packages of the yellow category up to 20 hours duration*

<table>
<thead>
<tr>
<th>Total number of radiation units shown on the packages</th>
<th>Minimum distance from nearest undeveloped film or plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10</td>
<td>meters 4.5, feet 15</td>
</tr>
<tr>
<td>11 to 20</td>
<td>meters 6, feet 20</td>
</tr>
<tr>
<td>21 to 30</td>
<td>meters 7.5, feet 25</td>
</tr>
<tr>
<td>31 to 40</td>
<td>meters 9, feet 30</td>
</tr>
</tbody>
</table>

The above Table covers journeys up to 20 hours; the special case of sea transport will be considered in Table VI. It may happen that transport by land or inland waterways exceeds this time, in which case the data given in Table VI may be used.

**Note:**

(a) The dose received is proportional to the duration of exposure and approximately proportional to:

(i) the total number of radiation units; and
(ii) the inverse of the square of the distance.

(b) The table is based on the requirement that for a journey of 20 hours duration, the total radiation received by the film will not exceed 10 mr.
## Table VI

**SAFE DISTANCES FOR PERSONS AND Carriage by sea of packages**

<table>
<thead>
<tr>
<th>Total number of radiation units shown on the packages**</th>
<th>Minimum distance† in meters from living accommodations or regularly occupied working space</th>
<th>Minimum distance† in meters*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-day voyage</td>
<td>9-day voyage</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Up to 1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2 to 5</td>
<td>7.5</td>
<td>3</td>
</tr>
<tr>
<td>6 to 10</td>
<td>10.5</td>
<td>4.5</td>
</tr>
<tr>
<td>11 to 25</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>26 to 50</td>
<td>27</td>
<td>9</td>
</tr>
<tr>
<td>51 to 100</td>
<td>40.5</td>
<td>12</td>
</tr>
<tr>
<td>101 to 200</td>
<td>58.5</td>
<td>16.5</td>
</tr>
<tr>
<td>201 to 300</td>
<td>70.5</td>
<td>21</td>
</tr>
<tr>
<td>301 to 400</td>
<td>79.5</td>
<td>24</td>
</tr>
</tbody>
</table>

Column A: No intervening cargo or bulkheads screening the radioactive materials from the living accommodation or undeveloped film or plate.

Column B: The radioactive materials to be surrounded by at least 0.6 m of cargo of unit density‡ and at least one steel bulkhead between the radioactive materials and the living accommodation or undeveloped film or plate.

---

* The corresponding distance in feet will be given with a satisfactory approximation by the following formula: distance (m) × 10/3 = distance (ft).

** For the purpose of this table, one category WHITE package or one package known to contain radioactive materials and subject to section 13 is considered to represent 1/10 of a radiation unit.

† Minimum distance means the minimum permissible in any direction, whether vertical or horizontal.
## UNDEVELOPED FILMS OR PLATES

containing radioactive materials

from nearest undeveloped film or plate

<table>
<thead>
<tr>
<th></th>
<th>16-day voyage</th>
<th>25-day voyage</th>
<th>36-day voyage</th>
<th>49-day voyage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>3</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>22.5</td>
<td>7.5</td>
<td>3</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>10.5</td>
<td>3</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>15</td>
<td>3</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>22.5</td>
<td>3</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>31.5</td>
<td>4.5</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>133.5</td>
<td>45</td>
<td>6</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>156</td>
<td>55.5</td>
<td>7.5</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>171</td>
<td>63</td>
<td>9</td>
<td>4.5</td>
<td></td>
</tr>
</tbody>
</table>

### Column C:
The radioactive materials to be surrounded by at least 2 m of cargo of unit density and at least two steel bulkheads between the radioactive materials and the living accommodation or undeveloped film or plate.

### Column D:
The radioactive materials to be surrounded by at least 4.2 m of cargo of unit density and at least two steel bulkheads between the radioactive materials and the living accommodation or undeveloped film or plate.

†† *Cargo of unit density* means cargo stowed at a density of 1 t (metric)/m³. Where the density is less than this, the depth of cargo specified in the notes on columns B, C and D, i.e., 0.6 m, 2 m and 4.2 m must be increased in proportion.

x Not to be carried unless screening by other cargo and bulkheads can be arranged in accordance with columns B, C and D.
### Table VII

**MINIMUM SEPARATION DISTANCES FROM PASSENGERS OR THE PUBLIC**

*(For carriage or storage up to 24 hours)*

<table>
<thead>
<tr>
<th>Total number of radiation units shown on the packages</th>
<th>Carriage or storage lasting less than 8 hours</th>
<th>Carriage or storage lasting from 8 to 24 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Separation distances (meters</td>
<td>feet)</td>
</tr>
<tr>
<td>0 to 10</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>11 to 20</td>
<td>1.2</td>
<td>4</td>
</tr>
<tr>
<td>21 to 30</td>
<td>1.5</td>
<td>5</td>
</tr>
<tr>
<td>31 to 40</td>
<td>1.8</td>
<td>6</td>
</tr>
</tbody>
</table>

* For carriage or storage on land or inland waterways exceeding 24 hours or for carriage by sea, the data given in Table VI may be used.

The above Table gives the separation distances related to the duration of carriage or storage of a yellow label package or packages in the vicinity of an area that may be continually occupied by passengers or the public.

**Note:**

(a) same as Note (a) Table V.

(b) These figures are such that a person exposed to the maximum number of radiation units for the maximum duration and at the corresponding distance would receive approximately 100 mrem.

### Table VIII

**MINIMUM SEPARATION DISTANCES FROM CREWS, DRIVERS, WAREHOUSE EMPLOYEES OR OTHER WORKERS ROUTINELY INVOLVED FOR AN AVERAGE WEEKLY TIME IN EXCESS OF 8 HOURS IN THE TRANSPORT OR STORAGE OF RADIOACTIVE SHIPMENTS**

*(For carriage or storage up to 24 hours)*

<table>
<thead>
<tr>
<th>Total number of radiation units shown on the packages</th>
<th>Carriage or storage lasting less than 8 hours</th>
<th>Carriage or storage lasting from 8 to 24 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Separation distances (meters</td>
<td>feet)</td>
</tr>
<tr>
<td>0 to 5</td>
<td>1.0</td>
<td>3.5</td>
</tr>
<tr>
<td>6 to 10</td>
<td>1.5</td>
<td>5</td>
</tr>
<tr>
<td>11 to 20</td>
<td>2.1</td>
<td>7</td>
</tr>
<tr>
<td>21 to 30</td>
<td>2.7</td>
<td>9</td>
</tr>
<tr>
<td>30 to 40</td>
<td>3.0</td>
<td>10</td>
</tr>
</tbody>
</table>

* For any other workers, the minimum separation distances given for passengers and the public shall be applied.

**For carriage or storage on land or inland waterways exceeding 24 hours or for carriage by sea, the data given in Table VI may be used.*
The preceding table gives the separation distances related to the duration of carriage or storage of any yellow label package or packages in the vicinity of an area that may be continually occupied by such workers.

**TABLE IX**

**RELATIONSHIP OF NEUTRON FLUX TO RADIATION UNIT**

<table>
<thead>
<tr>
<th>Energy of neutrons</th>
<th>Flux equivalent to 1 radiation unit (neutron/cm²s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.025 eV</td>
<td>267</td>
</tr>
<tr>
<td>10 eV</td>
<td>267</td>
</tr>
<tr>
<td>10 keV</td>
<td>133</td>
</tr>
<tr>
<td>0.1 MeV</td>
<td>27</td>
</tr>
<tr>
<td>0.5 MeV</td>
<td>11</td>
</tr>
<tr>
<td>1 MeV</td>
<td>8</td>
</tr>
<tr>
<td>2 MeV</td>
<td>5</td>
</tr>
<tr>
<td>3 to 10 MeV</td>
<td>4</td>
</tr>
</tbody>
</table>

**TABLE X**

<table>
<thead>
<tr>
<th>Emitter</th>
<th>Maximum permissible level of non-fixed radioactive surface contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta or gamma emitters</td>
<td>$10^{-4}$ $\mu$C/cm²</td>
</tr>
<tr>
<td>Alpha emitters</td>
<td>$10^{-5}$ $\mu$C/cm²</td>
</tr>
</tbody>
</table>

**Table XI**

**ACTIVITY-MASS RELATIONSHIPS**

<table>
<thead>
<tr>
<th>Fissile material and thorium</th>
<th>Toxicity group</th>
<th>c/g</th>
<th>g/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>${\text{U}}^{233}$</td>
<td>II</td>
<td>$9.48 \times 10^{-3}$</td>
<td>$1.05 \times 10^2$</td>
</tr>
<tr>
<td>${\text{Pu}}^{239}$</td>
<td>I</td>
<td>$6.17 \times 10^{-2}$</td>
<td>16.2</td>
</tr>
<tr>
<td>${\text{Pu}}^{240}$</td>
<td>I</td>
<td>$2.27 \times 10^{-1}$</td>
<td>4.41</td>
</tr>
<tr>
<td>$U^{235}$ (40%)</td>
<td>III</td>
<td>$2.08 \times 10^{-6}$</td>
<td>$4.81 \times 10^4$</td>
</tr>
<tr>
<td>$U^{235}$ (93%)</td>
<td>III</td>
<td>$6.99 \times 10^{-5}$</td>
<td>$1.43 \times 10^4$</td>
</tr>
<tr>
<td>$U^{235}$ (100%)</td>
<td>III</td>
<td>$2.14 \times 10^{-6}$</td>
<td>$4.67 \times 10^5$</td>
</tr>
<tr>
<td>Depleted uranium of about 0.3% U&lt;sup&gt;235&lt;/sup&gt; content</td>
<td>III</td>
<td>$4.37 \times 10^{-7}$</td>
<td>$2.29 \times 10^6$</td>
</tr>
<tr>
<td>Natural uranium</td>
<td>III</td>
<td>$6.85 \times 10^{-7}$</td>
<td>$1.46 \times 10^6$</td>
</tr>
<tr>
<td>Natural thorium</td>
<td>III</td>
<td>$5.6 \times 10^{-7}$</td>
<td>$1.8 \times 10^6$</td>
</tr>
</tbody>
</table>
1. When gamma- or X-radiation is produced and lead shielding or other equally efficient material of similar melting point is necessary to reduce the radiation to the levels specified in section 7, the shielding material should be encased in a shell of steel or another equally fire-resistant metal so designed that the shielding material will not flow away or lose its efficiency if involved in a fire. The shell should have a minimum wall-thickness as follows:
   (a) 3.18 mm (1/8 in) for a thickness of shielding material of 15.24 cm (6 in) or less; or
   (b) 6.36 mm (1/4 in) for a thickness of shielding material of more than 15.24 cm (6 in).

The shield should be free of voids that would reduce efficiency and should be supported in the outer container so that it cannot change position or open under any condition which may be encountered in transport. When the shield is not constructed in one piece, the sections should be designed so that there is no straight path from the inside of the shield to the outside along a joint between them.

2. For alpha and beta sources, when shielding is not necessary to reduce the radiation to the levels specified in section 7, the container should have a wall of steel or another equally fire-resistant metal with a thickness of not less than 1.59 mm (1/16 in) for up to 10 c and at least 3.18 mm (1/8 in) for greater than 10 c.

3. The hydrogenous shielding material incorporated where necessary in packages containing neutron sources or fissile material should be enclosed in a shell constructed of steel or another equally fire-resistant metal. The shell should have a minimum wall-thickness of:
   (a) 1.90 mm (1/16 in) for not more than 20 c; or
   (b) 3.18 mm (1/8 in) for greater than 20 c.

The shell should be equipped with a fusible plug, disc or other suitable vent designed to prevent rupture of the container should it be involved in a fire.

4. Liquid and readily volatile radioactive materials should be packed in a container made of stainless steel, malleable iron, brass or another equally effective metal having a wall-thickness of not less than 2.38 mm (3/32 in) for a diameter up to 5.08 cm (2 in) and not less than 3.18 mm

* Relating to type B packaging only; see paragraph 5.1.6.
(1/8 in) for a diameter up to 15.24 cm (6 in), with a proportionately thicker wall for containers with larger diameters. Ends of such containers should be closed by welding, brazing or screw-type closures. For openings exceeding 7.62 cm (3 in), securely bolted flange closures provided with suitable gaskets may also be used. Welding or brazing to join parts of the receptacle should be performed in a good workman-like manner and should provide a joint efficiency of not less than 85%. The melting point of the brazing material should be greater than 538°C (1000°F).

5. The shielding contained where necessary in the closure device should be completely enclosed in steel or another equally fire-resistant metal and should be designed so that there is no straight path from the inside of the shield to the outside along a joint between sections or where it has been inserted into other parts of the container. When the closure is held in position by means of threaded bolts or studs and nuts, the bolt or stud should not be less than 12.7 mm (1/2 in) in diameter. Unless additional devices are employed to secure the closure, bolts or studs should be spaced not more than 7.62 cm (3 in) apart and there should not be fewer than six such bolts or studs for any cover plate exceeding 193.5 cm² (30 in²) in area.

6. The exterior surfaces of packages should be free of protruding parts except for handling-trunnions, lifting devices or cooling fins. Other items, such as sample and relief valves and expansion tanks, should be recessed or protected from damage by steel guards.
ANNEX II

(Subject to further revision in the light of results of current studies)

CLASS I: SAFE FROM NEUTRON INTERACTION IN ANY ARRANGEMENT (see paragraph 15.2.1. of the regulations)

The condition “safe from neutron interaction in any arrangement” for a package containing fissile materials can be achieved by ensuring that the fissile materials are shielded from thermal neutrons and that when a source of neutrons suitably distributed* in angle and energy is placed at any point on the outside of the filled package, the number of epithermal neutrons leaving the package as a result are fewer than the number of neutrons entering it.

Geometrically limited packages

A type of package meeting these requirements consists of a 30.5 cm (12 in) diameter cylinder of wood, having a coaxial cylindrical cavity surrounded on all sides by at least a 10.2 cm (4 in) thickness of wood. The central cavity is cadmium-plated to a thickness of at least 0.38 mm (0.015 in), giving a minimum of 0.325 gCd/cm².

A square cross-section package measuring 30.5 cm (12 in) on each side is also suitable, provided the fissile materials are confined within the cylindrical diameters given below.

The fissile materials are confined within a circular cylinder of a diameter which depends on the density and the hydrogen content of the wood. Permissible diameters for various values of density and hydrogen content of the wood are shown in Fig. 1 for the respective materials listed below:

Curves A are for (1) Plutonium nitrate solutions.
Curves A are for (2)** Uranyl fluoride solutions.
(3)** Uranyl nitrate solutions.
(4)** Non-hydrogenous uranium compounds or mixtures in which the U²³⁵ concentration does not exceed 4.8 g/cm³.
(5)** Uranium metal of U²³⁵ enrichment not exceeding 25% by weight.

Curves B are for (1)** Non-hydrogenous uranium compounds or mixtures in which the U²³⁵ concentration does not exceed 9.6 g/cm³.
(2)** Uranium metal of U²³⁵ enrichment not exceeding 50% by weight.

* That is, with an angular distribution and energy spectrum at least as effective as that emerging from any container in this class.
** Uranium materials which do not include U²³⁵.
Curves C are for (1) Any material in which $^{235}\text{U}$ is the only fissile material and the $^{235}\text{U}$ concentration does not exceed 17.3 g/cm$^3$.

(2)* Uranium metal of $^{235}\text{U}$ enrichment not exceeding 92.1\% by weight.

Curves D are for (1) Non-hydrogenous plutonium compounds or mixtures in which the $^{239}\text{Pu}$ concentration does not exceed 10 g/cm$^3$.

Curves E are for (1) Any fissile material.

Curves F are for (1) $^{233}\text{U}$ fluoride solutions.

(2) $^{233}\text{U}$ nitrate solutions.

Mass-limited packages

For uranium or plutonium metal it may not always be possible to use the geometrically limited package. For such cases, a mass limitation can be imposed.

This type of package consists of a cadmium plating around the fissile materials with a thickness of at least 0.38 mm (0.015 in), giving 0.325 gCd/cm$^2$, surrounded by a thickness of at least 10.2 cm (4 in) of wood so that the minimum overall diameter of the package is no less than 30.5 cm (12 in).

The permissible mass of metal which depends on the density and hydrogen content of the wood is shown in Fig. 2 for the metals listed below:

Curves G are for uranium metal of $^{235}\text{U}$ enrichment not exceeding 92.1\% by weight and containing no $^{233}\text{U}$.

Curves H are for plutonium metal.

All the curves given in Figs. 1 and 2 are such that the criterion of “safe from neutron interaction in any arrangement” will be satisfied, even if a 1 cm layer of wood should be lost from the outer surface of the package through fire or accident.

* Uranium materials which do not include $^{233}\text{U}$.
Fig. 1

Packages in which geometry is the controlling factor

Note: the dashed lines apply to wood with 6.5% hydrogen by weight and the dotted lines are for wood with 6.9% hydrogen by weight.
Fig. 2

Packages in which mass is the controlling factor

Note: the dashed lines apply to wood with 6.5% hydrogen by weight and the dotted lines are for wood with 6.9% hydrogen by weight.
CLASS II: NUCLEARLY SAFE IN ANY ARRANGEMENT UNDER SPECIFIED CONDITIONS (see paragraph 15.2.2. of the regulations)

Explanatory statement
This Annex presents, in a step-by-step fashion, a method for determining the safe sizes of shipping containers for fissile materials and the allowable numbers of such packages which may be introduced on one mode of transport during any twenty-four hour period.

The figures in this Annex, as well as those given in sub-paragraph 6.2.2.1., are the results of calculations made with the purpose of ensuring that a criticality incident could not occur if one were to assume that five times the allowable number were to come together in one place through accident or other cause.

In the calculations, it was assumed that each package contained the maximum quantity of fissile material, that the outer dimensions of each package were the minimum acceptable under the regulations, and that optimum conditions of moderation were present.

Step 1: Determine the maximum size, $M_0$, of the fissile material unit from Table I.
(a) The relationship of the density of the fissionable material to its $H/X$ atom ratio* must conform to Figs. 1 or 2 or, if the density is exceeded, the maximum size must be reduced by the applicable ratio.

Step 2: Determine the maximum number, $N$, of containers of identical size and content allowed in an uncontrolled shipment.
(a) Calculate the volume $V$ defined by the outside dimensions of the shipping container. Enter Fig. 3 at this volume and read $N_0$, the allowable number of maximum-sized units, from the ordinate. This limit applies if all containers of the shipment have the same outer dimensions and if each contains the quantity of material given in Table I, so that, in this case, $N = N_0$.
(b) If $M$, the quantity of material in each container, is less than $M_0$ — the quantity allowed per container by Table I, the allowable number of such packages may be increased proportionately. Thus, the corrected limit is

$$N = N_0 \left( \frac{M_0}{M} \right)$$

* $H/X$ atom ratio shall mean the ratio of the number of hydrogen atoms to the number of atoms of the fissile materials (i. e., $^{235}\text{U}$, $^{233}\text{U}$ or $^{239}\text{Pu}$ atoms).
Table I
Mass and Volume Limits of Fissile Materials in Packages Subject to the Restriction of Fig. 3

<table>
<thead>
<tr>
<th></th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$^3\text{U}$</td>
</tr>
<tr>
<td>Metal, compounds, or mixtures, $H/X \leq 2^*$: mass limit, kg</td>
<td>5.0</td>
</tr>
<tr>
<td>Hydrogenous compounds or mixtures, $2 &lt; H/X &lt; 20^*$: mass limit, kg</td>
<td>1.0</td>
</tr>
<tr>
<td>Solutions, or hydrogenous mixtures, $H/X \geq 20^*$: volume limits, liters</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Containers are assumed to be of metal construction (nominal reflectors) and secure against leakage and water in-leakage. Reactor compositions and certain reflecting materials are excluded. The limit reductions for greater than the assumed densities of Figs. 1 and 2 must be applied to these values.

Note: For (1) and (2) in Table I, material volume of unit is not to exceed the safe volume for the isotopic composition of material being shipped as shown in Table II, or the container must comply with the safe dimensions given in Table II.

* $H/X$ signifies $H/^{233}\text{U}$, $H/^{239}\text{Pu}$ or $H/^{233}\text{U}$ atomic ratio.

** This limit holds for Pu metal at $p = 19.6$ g/cm³; for the alloy at $p = 15.8$ g/cm³, the corresponding limit is 5.0 kg.
### Table II

**VOLUME AND DIMENSION LIMITATIONS**

<table>
<thead>
<tr>
<th>U(^{235}) Assay (wt. % U(^{235}))</th>
<th>Volume 1 gal (US) cm</th>
<th>Diameter of cylinders of infinite length cm</th>
<th>Thickness of slabs of infinite area cm</th>
<th>Thickness of slabs of infinite area in</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.0</td>
<td>4.4</td>
<td>12.7</td>
<td>3.8</td>
<td>1.5</td>
</tr>
<tr>
<td>75.0</td>
<td>5.0</td>
<td>13.2</td>
<td>4.0</td>
<td>1.6</td>
</tr>
<tr>
<td>50.0</td>
<td>6.0</td>
<td>14.4</td>
<td>4.8</td>
<td>1.9</td>
</tr>
<tr>
<td>40.0</td>
<td>6.7</td>
<td>15.2</td>
<td>5.0</td>
<td>2.0</td>
</tr>
<tr>
<td>30.0</td>
<td>7.7</td>
<td>16.0</td>
<td>5.5</td>
<td>2.2</td>
</tr>
<tr>
<td>20.0</td>
<td>9.5</td>
<td>17.5</td>
<td>6.8</td>
<td>2.7</td>
</tr>
<tr>
<td>15.0</td>
<td>11.0</td>
<td>18.8</td>
<td>7.8</td>
<td>3.1</td>
</tr>
<tr>
<td>12.0</td>
<td>12.5</td>
<td>19.8</td>
<td>8.6</td>
<td>3.4</td>
</tr>
<tr>
<td>10.0</td>
<td>14.0</td>
<td>20.8</td>
<td>9.1</td>
<td>3.6</td>
</tr>
<tr>
<td>8.0</td>
<td>16.0</td>
<td>22.0</td>
<td>9.9</td>
<td>3.9</td>
</tr>
<tr>
<td>6.0</td>
<td>20.5</td>
<td>24.3</td>
<td>11.4</td>
<td>4.5</td>
</tr>
<tr>
<td>5.0</td>
<td>27.0</td>
<td>26.0</td>
<td>12.7</td>
<td>5.0</td>
</tr>
<tr>
<td>4.0</td>
<td>33.8</td>
<td>28.4</td>
<td>13.9</td>
<td>5.5</td>
</tr>
<tr>
<td>3.5</td>
<td>40.0</td>
<td>30.4</td>
<td>15.2</td>
<td>6.0</td>
</tr>
<tr>
<td>3.0</td>
<td>49.2</td>
<td>32.5</td>
<td>16.5</td>
<td>6.5</td>
</tr>
<tr>
<td>2.5</td>
<td>64.6</td>
<td>35.5</td>
<td>18.0</td>
<td>7.1</td>
</tr>
<tr>
<td>2.0</td>
<td>95.1</td>
<td>40.6</td>
<td>22.0</td>
<td>8.7</td>
</tr>
<tr>
<td>1.75</td>
<td>126.0</td>
<td>44.7</td>
<td>24.3</td>
<td>9.6</td>
</tr>
<tr>
<td>1.5</td>
<td>186.0</td>
<td>50.8</td>
<td>27.9</td>
<td>11.0</td>
</tr>
<tr>
<td>1.25</td>
<td>308.0</td>
<td>60.9</td>
<td>34.2</td>
<td>13.5</td>
</tr>
<tr>
<td>1.0</td>
<td>731.0</td>
<td>83.8</td>
<td>49.5</td>
<td>19.5</td>
</tr>
<tr>
<td>0.8</td>
<td>3917.0</td>
<td>147.3</td>
<td>91.4</td>
<td>36.0</td>
</tr>
<tr>
<td>0.72</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
</tr>
</tbody>
</table>

Tabulated values give the maximum permissible inside dimensions of the receptacle (inner container) or the maximum permissible internal volume of the receptacle. See also Table I.
Assumed densities of $X$ ($\text{U}^{235}$, $\text{U}^{233}$ or $\text{Pu}^{239}$) at $H/X$ less than 20

If a material density exceeds the indicated value by the ratio $n$, reduce mass limits by the factor $1/n^2$, volume limits by $1/n^3$, and linear dimension limits by $1/n$. No relaxation is allowed for material densities below the indicated value.

I $\text{Pu}^{239}$ maximum density  
II $\text{U}^{233}$ maximum density  
III $\text{U}^{235}$ maximum density  
IV Metal-water mixtures
Fig. 2

Assumed densities of $X$ ($^{235}\text{U}$, $^{233}\text{U}$ or $^{239}\text{Pu}$) at $H/X$ greater than 20

If a material density exceeds the indicated value by the ratio $n$, reduce mass limits by the factor $1/n^2$, volume limits by $1/n^3$, and linear dimension limits by $1/n$. No relaxation is allowed for material densities below the indicated value.
Fig. 3
Allowable number of packages in uncontrolled shipments of units as defined in Table I — cubic arrays — optimum water moderators and reflectors
Page 36: *Insert a new paragraph 15.2.2.6 as follows:*

"15.2.2.6 Class II packages shall carry the yellow label where the figure indicating the number of radiation units shall be taken as the larger of:

(a) the number of radiation units as defined in para. 1.1.5;

or (b) the number obtained by dividing the available number $N$ (Annex III, Step 2) into 40."

Page 66: *Insert immediately before Step 1: “Each package must provide at least 20 cm (8 in) surface-to-surface separation between the inner containers of fissile materials”.*

Page 68: *Replace Table II by the following:*

**Table II**

**Volume and Dimension Limitations**

Either the internal volume or the inside diameter (if the container is cylindrical), or the smallest dimension of the inner container shall not exceed the values given below:

<table>
<thead>
<tr>
<th>Fissile isotope</th>
<th>Assay</th>
<th>Volume</th>
<th>Diameter</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>liters</td>
<td>gal (US)</td>
<td>cm</td>
</tr>
<tr>
<td>Pu$^{239}$</td>
<td>any</td>
<td>3.4</td>
<td>0.90</td>
<td>10.6</td>
</tr>
<tr>
<td>U$^{233}$</td>
<td>any</td>
<td>2.3</td>
<td>0.61</td>
<td>9.4</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>exceeding 50%</td>
<td>4.8</td>
<td>1.27</td>
<td>12.7</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>not exceeding 50%</td>
<td>7.4</td>
<td>1.9</td>
<td>14</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>&quot;</td>
<td>30%</td>
<td>8.4</td>
<td>2.2</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>&quot;</td>
<td>20%</td>
<td>10.3</td>
<td>2.7</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>&quot;</td>
<td>10%</td>
<td>15</td>
<td>3.9</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>&quot;</td>
<td>7%</td>
<td>19</td>
<td>5.0</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>&quot;</td>
<td>5%</td>
<td>29</td>
<td>7.7</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>&quot;</td>
<td>3%</td>
<td>53</td>
<td>14</td>
</tr>
<tr>
<td>U$^{235}$</td>
<td>&quot;</td>
<td>2%</td>
<td>104</td>
<td>27</td>
</tr>
</tbody>
</table>

If the contents contain a mixture of fissile isotopes the more restrictive limitation should be applied.
OTHER AGENCY PUBLICATIONS IN THE SAFETY SERIES

No. 1 — SAFE HANDLING OF RADIOISOTOPES — STI/PUB/1
100 p. (14.8 × 21 cm) — (B) — US $ 1; 6s.0d.stg; Sch 21
This Manual, prepared by an international group of experts in consultation with other international agencies, covers medical, technical and organizational aspects of safety practices and deals with maximum permissible levels for exposure to radiation, organization of safety, medical supervision of workers, monitoring and records, use, storage and transportation of sealed and unsealed sources, accidents, decontamination and waste disposal. Available in English, French, Russian and Spanish.

No. 2 — SAFE HANDLING OF RADIOISOTOPES — HEALTH PHYSICS ADDENDUM — STI/PUB/10
120 p. (14.8 × 21 cm) — (B) — US $ 1.50; 9s.0d.stg; Sch 31.50
The Health Physics Addendum is one of two supplements to the Manual on “Safe Handling of Radioisotopes”, which the IAEA published in 1958. It contains technical information needed by health physicists in implementing the controls recommended in the Manual and was compiled by the Agency’s Secretariat on the basis of material prepared by two of the expert members of the Panel whose recommendations form the text of the Manual itself. A valuable feature of the Addendum is the Annex of useful health physics data in the form of tables, diagrams and illustrations of instruments. Available in English, French, Russian and Spanish.

No. 3 — SAFE HANDLING OF RADIOISOTOPES — MEDICAL ADDENDUM — STI/PUB/11
80 p. (14.8 × 21 cm) — (B) — US $ 1.50; 9s.0d.stg; Sch 31.50
The Medical Addendum is one of two supplements to the Manual on “Safe Handling of Radioisotopes”, which the IAEA published in 1958. It contains technical information needed by medical officers in implementing the controls recommended in the Manual and was compiled by the Agency’s Secretariat on the basis of material prepared by two of the expert members of the Panel whose recommendations form the text of the Manual itself. It also contains a useful bibliography of the relevant international literature. Available in English, French, Russian and Spanish.

This publication is no longer valid
Please see http://www-ns.iaea.org/standards/
No. 4 — SAFE OPERATION OF CRITICAL ASSEMBLIES AND RESEARCH REACTORS — STI/PUB/29

This Manual was prepared by the Agency's Secretariat, after careful consideration of existing national safety practices, with the assistance of an international panel of experts and in consultation with other international bodies concerned, in order to meet an urgent need for a manual of practices in the safe operation of critical assemblies and research reactors. Many suggestions are included which also concern the organizational and administrative side of reactor operation. The manual, therefore, is a useful guide not only for technical men but also for various authorities and persons otherwise responsible for the use of such equipment.

Available in English, French, Russian and Spanish.

No. 5 — RADIOACTIVE WASTE DISPOSAL INTO THE SEA — STI/PUB/14

This document, which has become known as the “Brynielsson Report”, is the report of a panel convened by the Agency's Director General and presided over by Mr. Harry Brynielsson, managing director of AB Atomenergi (Sweden). While it does not necessarily express the views on this subject either of the Agency or of the bodies to which the individual panel members belong, it represents the general considered opinion of a group of distinguished scientists and other experts, who believe that waste disposal operations can be controlled in such a way as to safeguard man against the deleterious effects of radiation. A series of recommendations for an international agreement to that effect is offered, together with material for the practical guidance of those who are technically concerned with radioactive waste disposal into the sea.

Available in English, French, Russian and Spanish.

No. 7 — REGULATIONS FOR THE TRANSPORT OF RADIOACTIVE MATERIALS: NOTES ON CERTAIN ASPECTS OF THE REGULATIONS — STI/PUB/32

(in press)

This booklet contains background information on the Regulations for the Safe Transport of Radioactive Materials (Safety Series No. 6). On the one hand, some of the scientific considerations which led to the specific limits laid down in the Regulations are discussed; on the other, the practical information it contains on the meaning and use of the Regulations, including a "layman's guide", a synoptic table, guidance on packaging, etc., will be of value to transporters of radioactive materials who are called upon to comply with the Regulations.
This publication is no longer valid
Please see http://www-ns.iaea.org/standards/

IAEA SALES AGENTS

ARGENTINA
Editorial Sudamericana, S. A.
Alaina 300
Buenos Aires

AUSTRALIA
Melbourne University Press
369, Lonsdale Street
Melbourne, C. 1

AUSTRIA
Georg Fromme & Co.
Spengergasse 39
Vienna V

BELGIUM
Office international de librairie
30, avenue Marnix
Brussels 5

BRAZIL
Livraria Kosmos Editora
Rua do Rosario, 135–137
Rio de Janeiro
Agencia Expoente Oscar M. Silva
Rua Xavier de Toledo, 148–1º Andar
(Caixa Postal No. 5814)
São Paulo

BURMA
See under India

BYELORUSSIAN SOVIET SOCIALIST REPUBLIC
See under USSR

CEYLON
See under India

CHINA (Taiwan)
Books and Scientific Supplies
Service, Ltd.,
P. O. Box 83
Taipei

DENMARK
Ejnar Munksgaard Ltd.
6 Nørregade
Copenhagen K

ETHIOPIA
G. P. Giannopoulos
International Press Agency
P. O. Box 120
Addis Ababa

FRANCE and FRENCH UNION
Masson et Cie, Editeurs
120 bd Saint-Germain
Paris 7°

GERMANY, Federal Republic of
R. Oldenburg
Rosenheimer Straße 145
Munich 8

GREECE
C. Eleftheroudakis and Son
Constitution Square
Athens

ICELAND
Halldéjónsson
Mjóstraeti 2
Reykjavik

INDIA
Orient Longmans Private Ltd.
17, Chittaranjan Ave.
Calcutta 13

ISRAEL
Heiliger and Co.
3 Nathan Strauss Street
Jerusalem

ITALY
Agenzia Editoriale Internazionale
Organizzazioni Universali
(A. E. I. O. U.)
Via Meravigli 16
Milan

JAPAN
Maruzen Company Ltd.
6, Tori Nichome
Nihombashi
P. O. Box 805
Tokyo Central

KOREA, Republic of
The Eul-Yoo Publishing Co.
5,2-ka Chong-ro
Seoul

MONACO
The British Library
30, bd des Moulins
Monte Carlo

MOROCCO
Centre de diffusion documentaire
du B. E. P. I.
8, rue Michaux-Bellaire
(B. P. No. 211)
Rabat

NEPAL
See under India

NETHERLANDS
N. V. Martinus Nijhoff
Lange Voorhout 9
The Hague

NEW ZEALAND
Whitcombe & Tombs, Ltd.
C. P. O. Box 1894
Wellington, C. 1

EAST PAKISTAN
See under India