RADIOACTIVE SUBSTANCES TRANSPORT

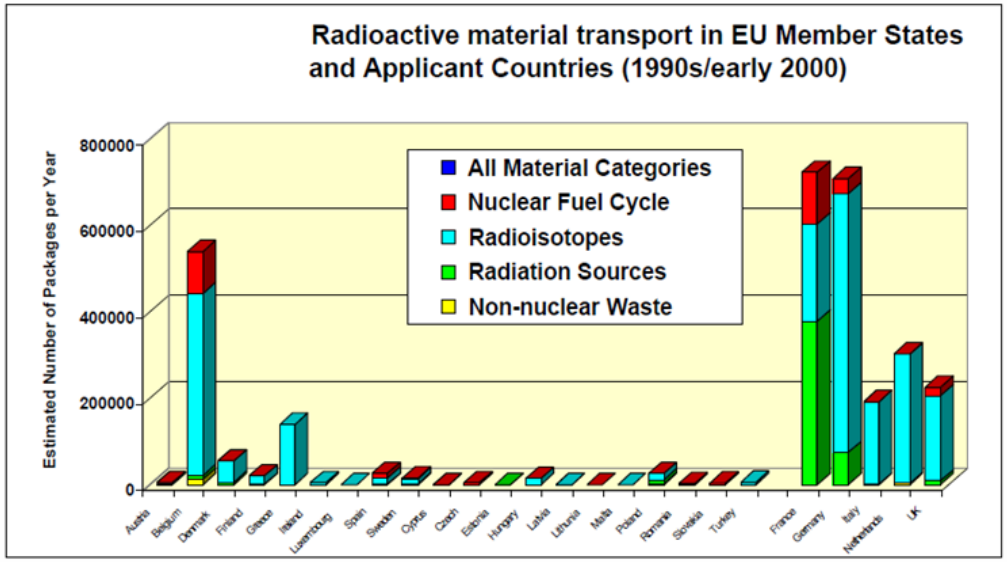
Safety depends primarily upon the package

Victoria Corregidor

The numbers…

- Only 5% of radioactive transport is for nuclear spent fuel
- 20 million packages by road, sea and air per year
- In 2009: 70.000 diagnosis scans using nuclear products
- 99Mo, world demand:
  - In 2012: 23.000 TBq/year
  - In 2016: 19.500 TBq/year
- 99Mo, half-live: 66h
- **7** . Class number: Radioactive Material

The numbers



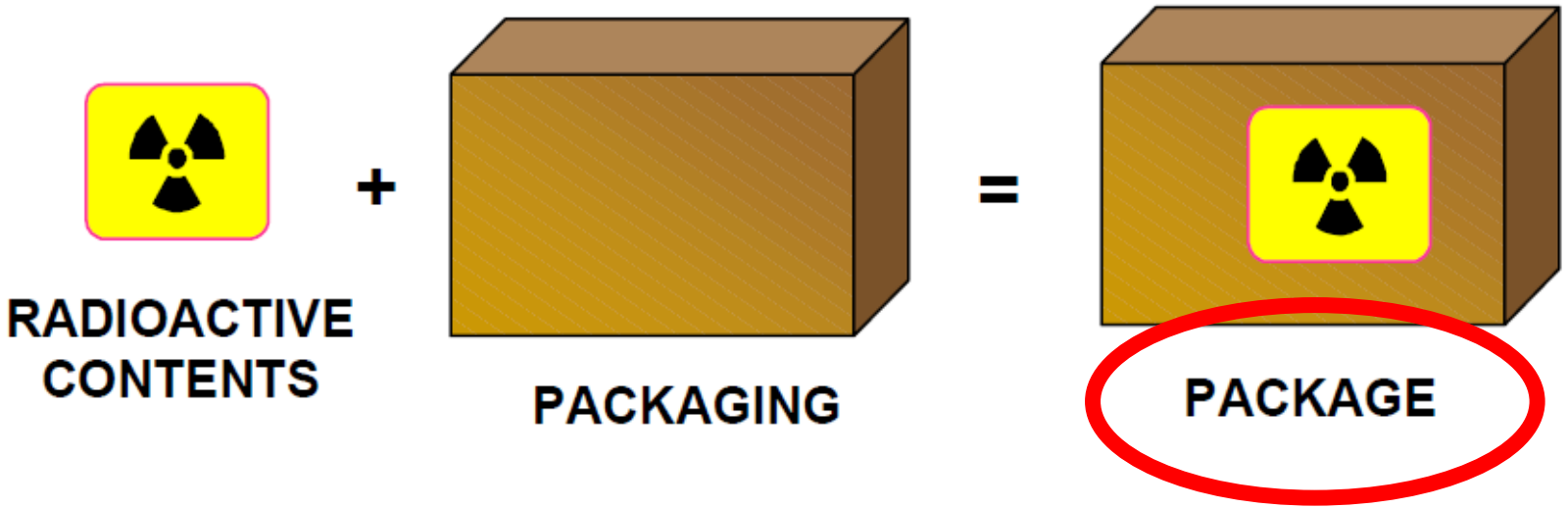
Radioactive material transport in EU Member States and applicant countries (1990-2000)

So…

So…

Radioactive materials usually are transported in public ships, airplanes and roads

The image

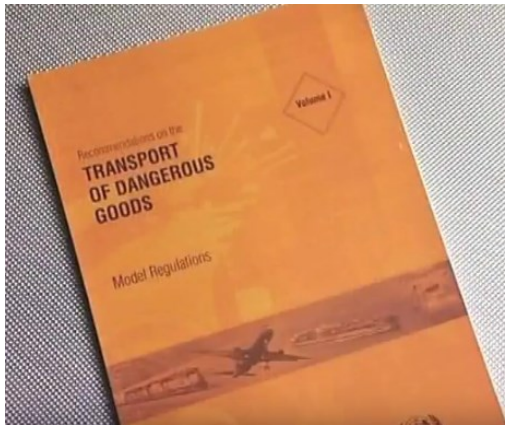


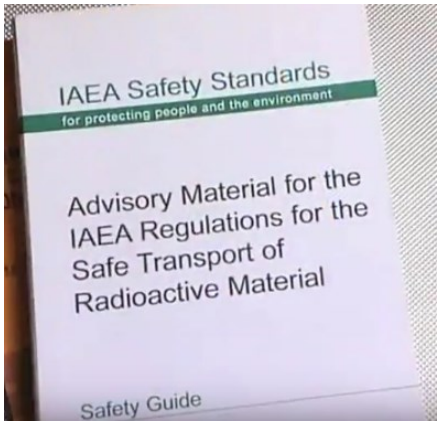
The **package**, as indicated in Figure, is the packaging with its radioactive contents as presented for transport,
the **packaging** is the assembly of components necessary to enclose the radioactive contents completely.

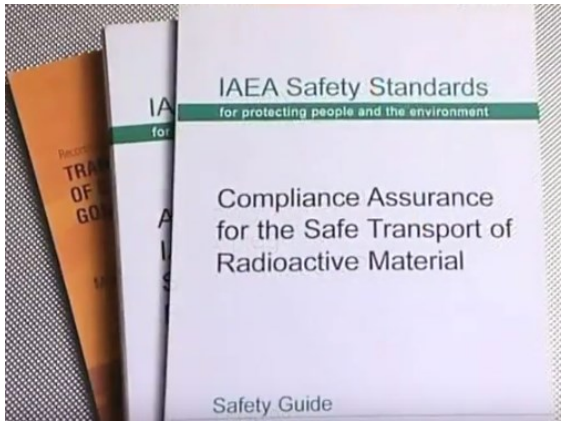
The words…

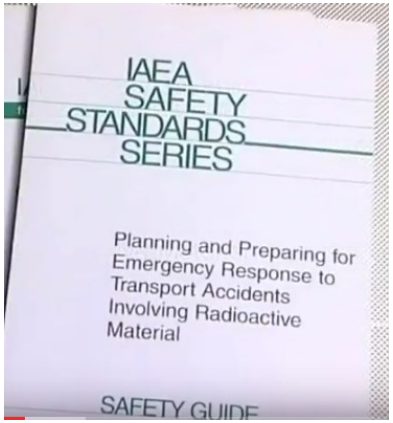

package
test
transport
Regulations
materials
activity
must
packages
radioactive
Type-A
contents
Type
Transport
material
Radioactive

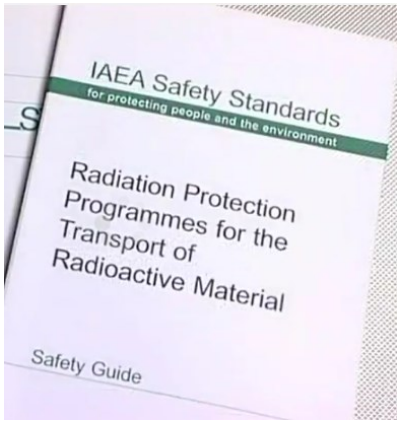
Regulations from the IAEA

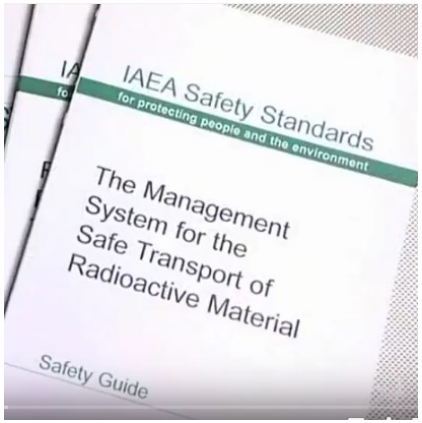






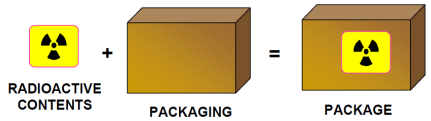






At the IAEA there is a lot of documentation, REGULTATIONS that must be followed by all the members.

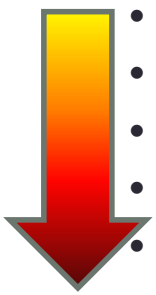
Packages



The package integrity is function of the **hazard associated with the radioactive** material:
the more hazardous the material, the harder /complex will be the packaging.

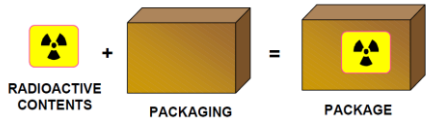
The **size is not related with the hazardous** of the material, some small packages may contain very large quantities of radioactivity.

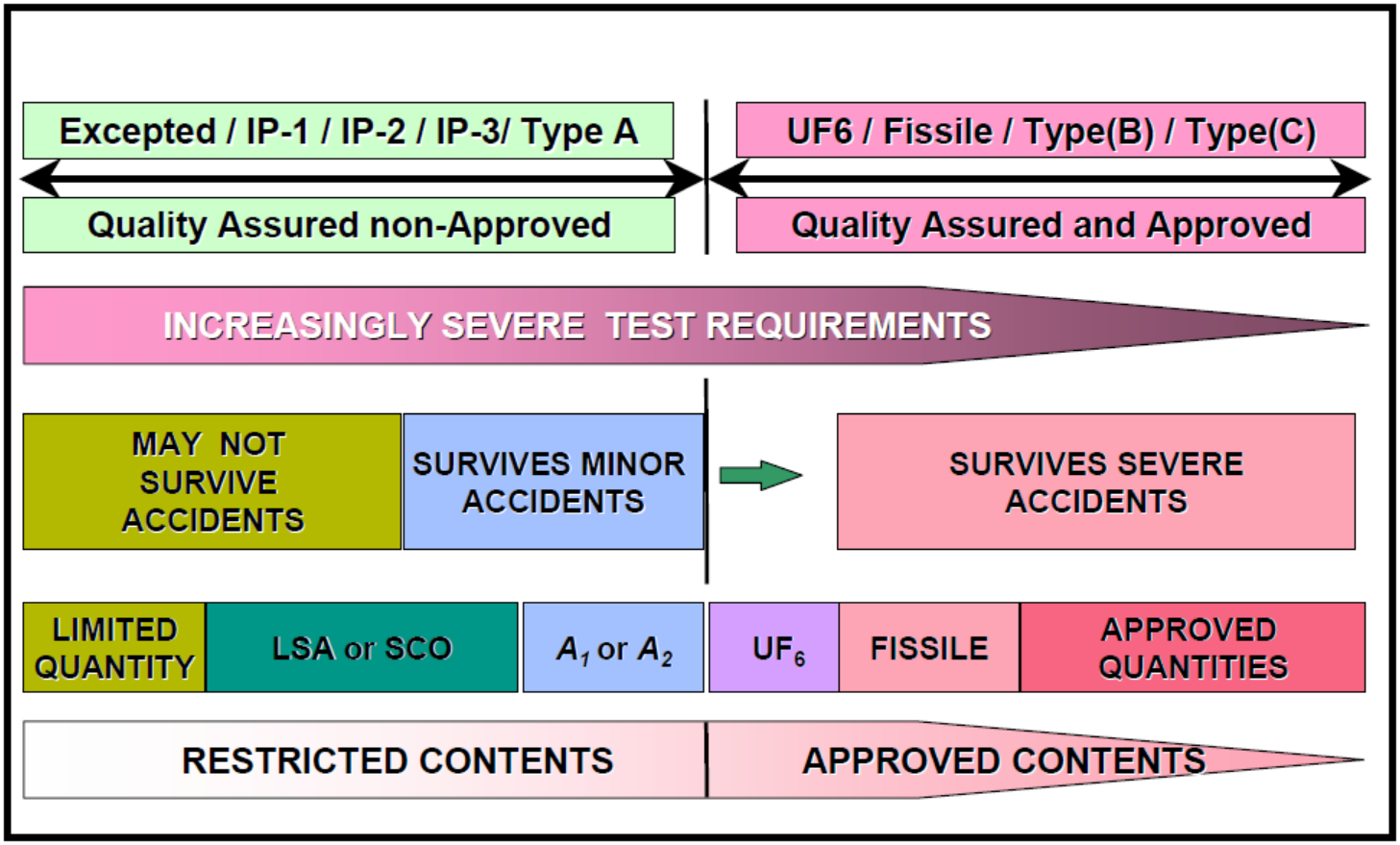
According with the activity of the radioactive contents, there are five different types of packages:



- Excepted packages;
- Industrial package (Type IP-1, Type IP-2 and Type IP-3);
- Type A;
- Type B (Type B(U), TYPE B(M));
- Type C.

Packages design





Some materials and packages do not need a formal approval about the design (Excepted, Industrial and Type A packages) but others (Type B and Type C packages) need a formal approval

Packages tests

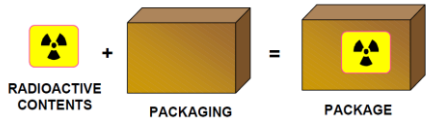


Table 2. General design requirements for all package types [3].

	Excepted package	IP-1	IP-2	IP-3	Type A	Type B	Type C
General requirements							
Handling, lifting, vibration, acceleration, material compatibility	X	X	X	X	X	X	X

Table 3. Package test requirements for normal conditions of transport [3].

	Excepted package	IP-1	IP-2	IP-3	Type A	Type B	Type C
Drop test 0.3-1.2 m			X	X	X	X	X
Stacking			X	X	X	X	X
Water spray				X	X	X	X
Penetration							
1.0 m				X	X	X	X
1.7 m					L,G		

L,G. Liquid or gases content

Packages tests

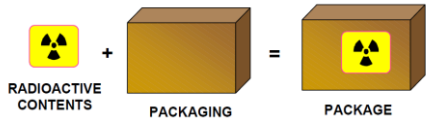


Table 4. Package test requirements for accident conditions of transport [3].

	Excepted package	IP-1	IP-2	IP-3	Type A	Type B	Type C
Drop test 9 m					L,G	HHD	X
Penetration 1m						X	
Crush test 9 m						LLD	X
Thermal test						X	
Water immersion 15 m						X	
Water immersion 200 m						LC	X
Puncture/tearing							X
Enhanced thermal test							X
Impact test							X
Water leakage test for criticality	All packages containing fissile material						

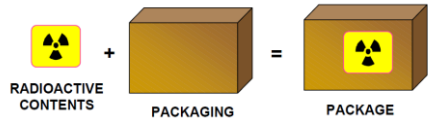
L,G. Liquid or gases content

HHD. Heavy weight/High density packages

LLD. Lightweight/Low density pacakges

LC. Packages with large quantity contents($>10^5$A2)

Packages tests



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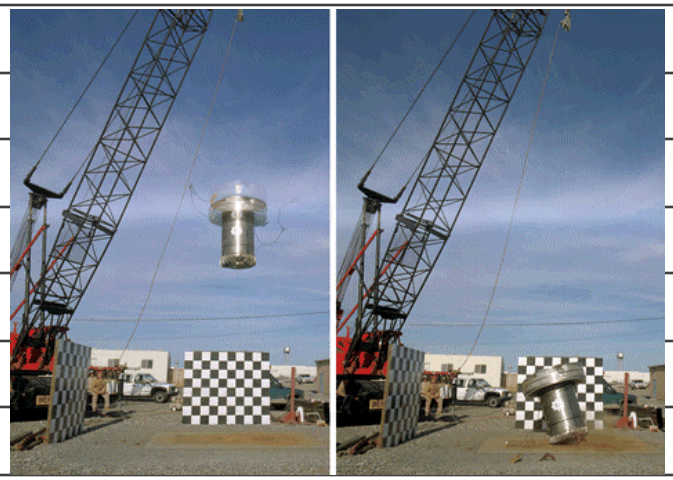
Thermal test						X	
Water immersion 15 m						X	
Water immersion 200 m						LC	X
Puncture/tearing							X
Enhanced thermal test							X
Impact test							X
Water leakage test for criticality	All packages containing fissile material						



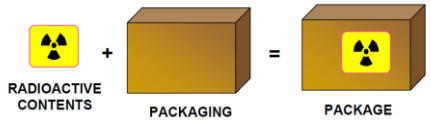
L,G. Liquid or gases content

LLD. Lightweight/Low density pacakges

HHD. Heavy weight/High density packages

LC. Packages with large quantity contents($>10^5$A2)

Packages tests



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Thermal test						X	
Water immersion 15 m						X	
Water immersion 200 m						LC	X
Puncture/tearing							X
Enhanced thermal test							X
Impact test							X
Water leakage test for criticality	All packages containing fissile material						

L,G. Liquid or gases content

LLD. Lightweight/Low density pacakges

HHD. Heavy weight/High density packages

LC. Packages with large quantity contents($>10^5$A2)

The labels

Ones the radioactive contents are protected/shielded/secured, they must be “announced”

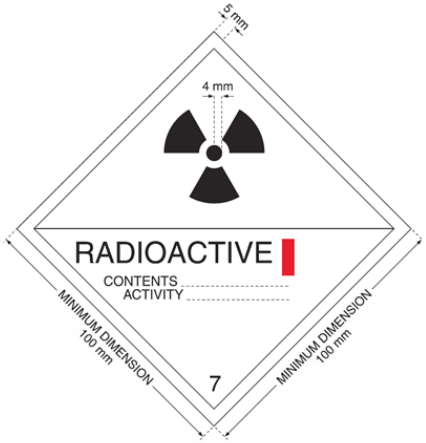


Figure 7. Category I-WHITE label. The background colour of the label shall be white, the colour of the trefoil and the printing shall be black, and the colour of the category bar shall be red.

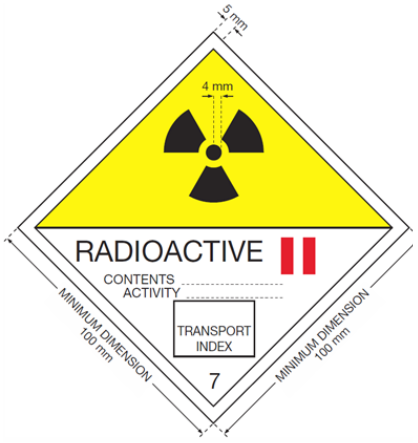


Figure 8. Category II-YELLOW label. The background colour of the upper half of the label shall be yellow and the lower half white, the colour of the trefoil and the printing shall be black, and the colour of the category bars shall be red.

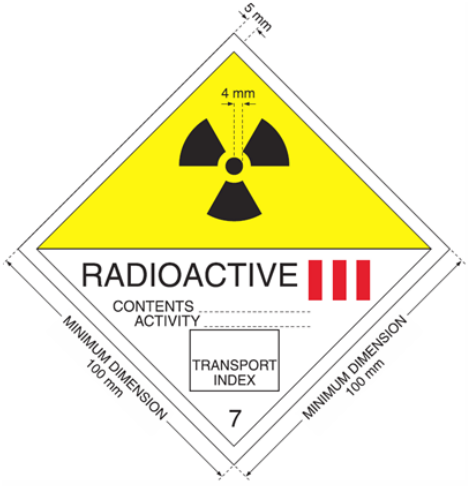


Figure 9. Category III-YELLOW label. The background colour of the upper half of the label shall be yellow and the lower half white, the colour of the trefoil and the printing shall be black, and the colour of the category bars shall be red.

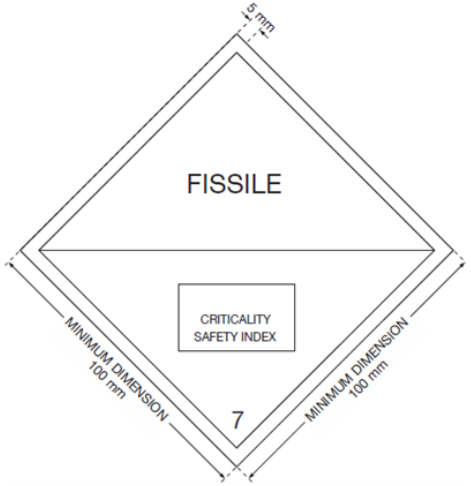


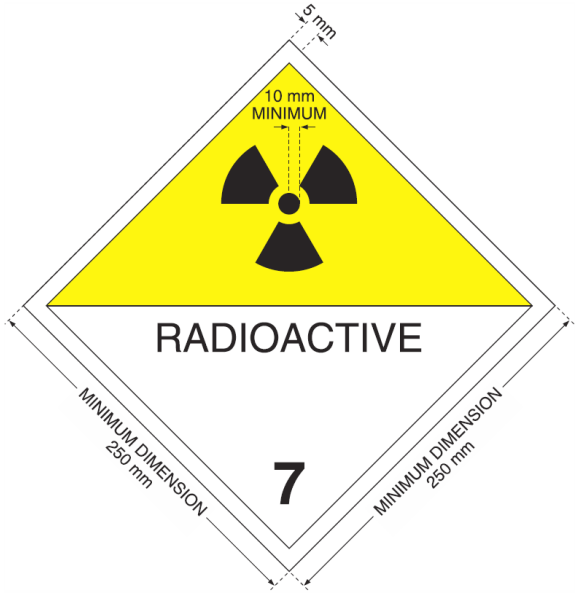
Figure 10. CSI label. The background colour of the label shall be white, the colour of the printing shall be black.

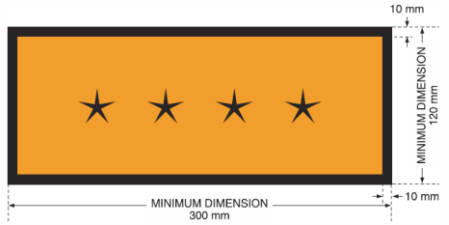
Category Yellow II, 0.5 mSv/hr maximum at surface or has a TI lower than 1.
Category Yellow III 2 mSv/hr maximum at surface or has a TI lower than 10.

The placards

The placards inform:

- the public - the presence of hazards while they're driving or near large quantities of hazmat being transported.
- The emergency responders - may be the only way they know what materials are involved in the accident.



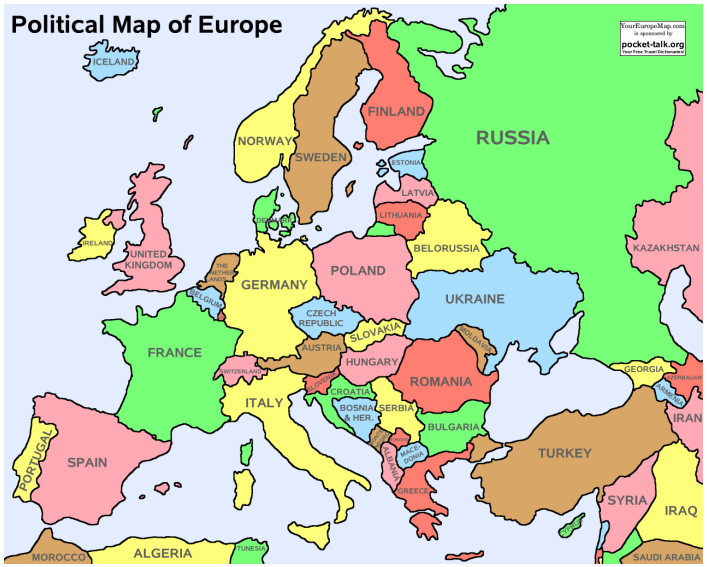


The symbol "****" denotes the space in which the appropriate UN number for radioactive material, as specified in Table 1 of SSR-6

In this work two different situation were considered:

- 60Co sources transport from Russia to the Technological Unit of Radiosterilization at Campus Tecnológico e Nuclear (CTN-IST):
    - Curiosity,
    - Opportunity (half life about 5 years).
- Radionuclides and radiopharmaceutical products transport:
    - Curiosity,
    - The more transported,
    - Higher probability to find them….

60Co sources transport



Russia – Belgium – Portugal

sea road

Many other countries involved

and National/International Institutions:

ROSATOM: Russian Federation national nuclear corporation
IAEA: International Atomic Energy Agency
FANC The Federal Agency for Nuclear Control, Belgium
DGS Direção-Geral da Saúde, Portugal
…
…

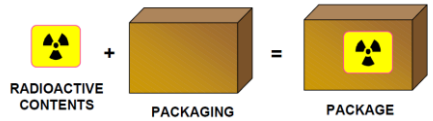
60Co package

A Type B(U) package:

The Regulations do not specify activity limits. The activity limits are generally established during design.

The design must be approved and tested.

Packages tests



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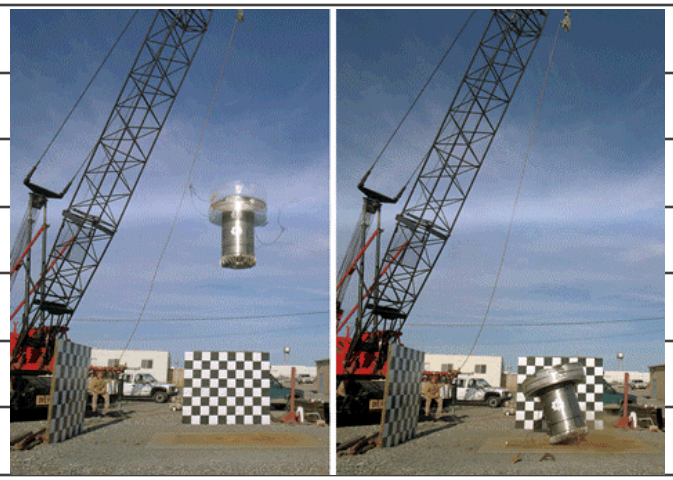
Thermal test						X	
Water immersion 15 m						X	
Water immersion 200 m						LC	X
Puncture/tearing							X
Enhanced thermal test							X
Impact test							X
Water leakage test for criticality	All packages containing fissile material						



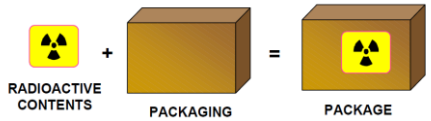
L,G. Liquid or gases content

LLD. Lightweight/Low density pacakges

HHD. Heavy weight/High density packages

LC. Packages with large quantity contents($>10^5$A2)

Packages tests



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L,G. Liquid or gases content

LLD. Lightweight/Low density pacakges

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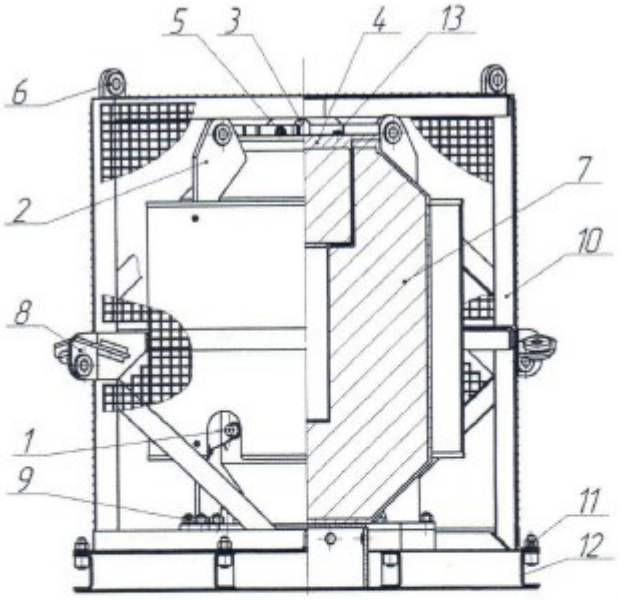
LC. Packages with large quantity contents($>10^5$A2)

60Co package



1. Vent Plug (stainless steel)
2. Rib with Lift Interface (stainless steel)
3. Plug Lift Interface (stainless steel)
4. Container Plug (stainless steel, lead)
5. M1 Nut (stainless steel)
6. Lift Interface(stainless steel)
7. Container Body (stainless steel)
8. Tie-down Point
9. M20 Nut (stainless steel)
10. Cage (stainless steel)
11. M20 Nut (stainless steel)
12. Skid (stainless steel)
13. G Screw (stainless steel)for covering the inert-gas filling hole

Dimensions, mm			Nominal Weight	Weight Tolerances, kg
Length	Width	Height		
1360	1360	1470	4332	+168 - 217

60Co package

Principal Use

УКТ1В-160000/4300 Transport Packages (further referred to as TP), зав. №№001÷100 made to TS 95 2884-2005 Technical Specifications are used to store and transport Co-60 and Cs-137 sealed sources of ionizing radiation which qualify as Special Form Radioactive Materials (SFRM).

Authorized Radioactive Content

Co-60 and Cs-137 sealed sources of ionizing radiation which qualify as Special Form Radioactive Materials (SFRM) and valid Special Form certificates must be available. Maximum activities of sealed sources to be shipped in the TP are specified in the table below:

Table 1

Radionuclide	TP Max Activity, TBq (Ci)
Co-60	5920 (160000)
Co-60	6660 (180000)*
Cs-137	6660 (180000)

Note: * Radionuclide activity for exclusive use shipments.

When transported by air, the total activity of Co-60 and Cs-137 sources must not exceed 1200 T Bq (32.4 kCi), and 5994 TBq (162 kCi) respectively.

60Co package

Shipping Conditions and Restrictions

The TP shall be shipped by any mode of transport without restrictions.

Shipping by air shall meet the restrictions specified in Authorized Radioactive Content section herein.

Precautions for Class 7 Dangerous Goods set out in GOST-19433-88 (National Standard) Dangerous Goods Transportation shall be adhered to as provided for each mode of transportation. The transport packages are shipped under Category III-Yellow or below (max Transport Index 10).
The number of TPs per vehicle shall be so as the TI does not exceed 50. In air carriage, the total TI shall not exceed 50 for passenger aircraft and 200 for cargo aircraft.
precautions are adhered to under GOST-19433-88 (National Standard) as provided for each mode of transportation.

Under normal conditions, the dose at any point on the outer surface of the transport package shall not exceed 2 mSv/h (200 mrem/h), and 0.1 mSv/h (10 mrem/h) at a 2-meter distance away.

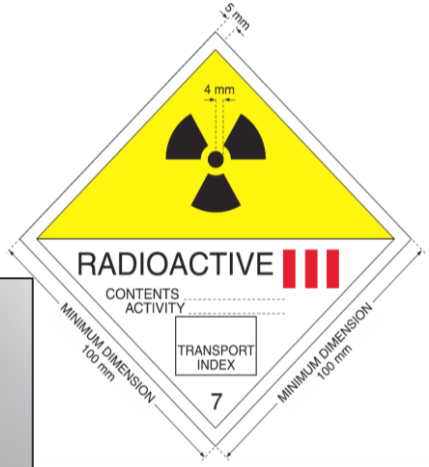
To prevent overheating, the following stacking arrangements shall be observed:

1. If the total activity does not exceed Co-60: 160 TBq (4324 kCi) and Cs-137: 510TBq (13784 kCi) which correlates with a 15W/m^2 heat flux rate from the top of the TP, no special stacking arrangements are required.
2. If the total activity is in excess of the abovementioned values,

- no covering the TP surface with heat-retaining materials (e.g tarpaulin) resulting in reduced air cooling is permitted;
- no stacking on top of other cargo packages is permitted;

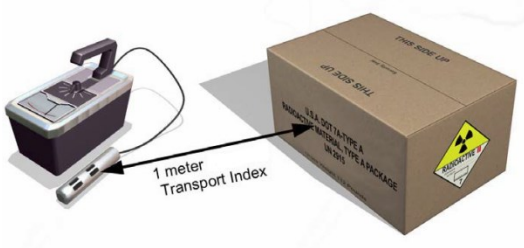
- when storing the Transport Package indoors, the clearance between the top surface and the

60Co package label

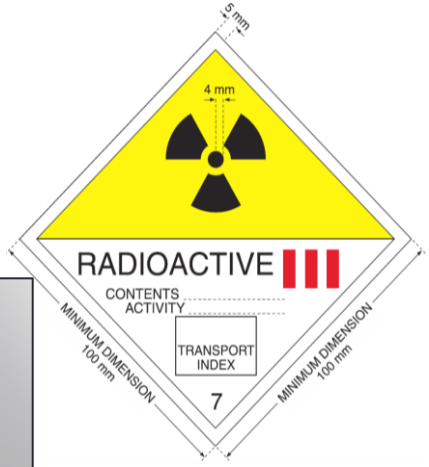


Contents: Co-60
Activity: 5098,23TBq
Transport Index: 6.1
UN Class number: 7

Transport Index, TI: provides control over radiation exposure and establish transport controls.
maximum radiation level measured (mSv/hr) at one meter from the package multiplied by 100.



60Co package label



Contents: Co-60
Activity: 5098,23TBq
Transport Index: 6.1
UN Class number: 7

Shielding!!!!!!!!!!!

60Co package placards

The label, and the UN number

Gamma radionuclides

From IAEA

Radionuclides and radiopharmaceutical products

Many of these radionuclides are produced in reactors or cyclotrons;

99mTc is by far the most used because its versatility and easy access;

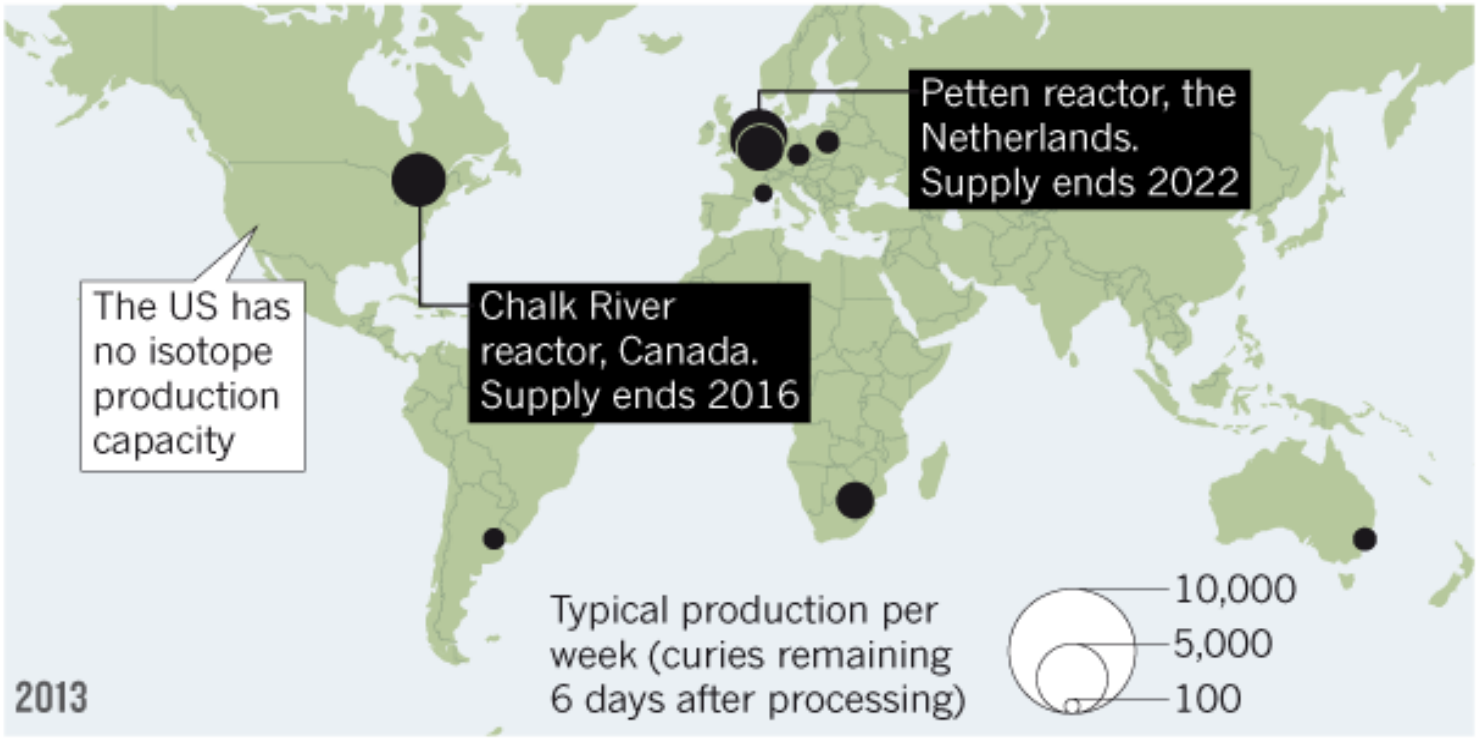
In 2009 the number of diagnostic scans using 99mTc was about 70.000;

Within most industrialized countries, hundreds, and even thousands, of isotope packages are transported daily, the majority by road.

Reactor radioisotopes			
	Emission type	Used for	half-life
213-Bi	Alpha (8.4 MeV)	Cancer treatment	46 min
131-Cs	Soft X-rays	Brachytherapy	9.7 d
137-Cs		Blood sterilisation	30 yr
125-I		cancer brachytherapy (prostate and brain)	60 d
131-I	strong gamma emitter, but used for beta therapy	treating thyroid cancer and in imaging the thyroid; diagnosis of abnormal liver function, renal (kidney) blood flow and urinary tract obstruction	8 d
99-Mo		Used as the 'parent' in a generator to produce 99mTc	66 h
99m-Tc	Gamma	The most common radioisotope for diagnosis, accounting for over 80% of scans.	6 h
32-P	Beta	treatment of polycythemia vera (excess red blood cells)	14 d
153-Sm	Beta	relieve the pain of secondary cancers lodged in the bone. Also very effective for prostate and breast cancer	47 h
89-Sr	Beta	Reduce the pain of prostate and bone cancer	50 d
Cyclotron radioisotopes			
11-C 13-N 15-O 18-F	positrons	used in PET for studying brain physiology and pathology	20.4 s 9.9 s 2.1 s 109.7 m
64-Cu	Positrons	PET imaging of tumours, and also cancer therapy	13 h
67-Cu	Beta	Therapy	2.6 d
68-Ga	Positron	PET and PET-CT units. Derived from germanium-68 in a generator.	68 min
123-I	gamma	diagnosis of thyroid function	13h
124-I	positron	image the thyroid using PET	4.2 d

Radionuclides and radiopharmaceutical products

The main world radionuclides suppliers are Mallinckrodt Pharmaceuticals (Ireland), AECL/MDS Nordion (Canada), IRE (Europe), NTP (South Africa), Isotop-NIIAR (Russia) and ANSTO (Australia).



Radionuclides and radiopharmaceutical products

In Portugal, the data about the production of radioisotopes are scarce.
As far as my knowledge there are two cyclotrons which produces them, one is in Matosinhos (Porto) which is private and the other is in Coimbra, at ICNAS (Instituto de Ciências Nucleares Aplicadas à Saude). None of them offer any information in their websites.

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Radionuclides and radiopharmaceutical products

Radioisotopes as 18-F, 13-N, 11-C, 82-Rb and 68-Ga are commercialized as 18FDG, 18F-Colina, Na18F, 68Ga-DotaNOC e 18F-DOPA by ISODER SA [19], in partnership with ICNAS and IBA Molecular in Spain [20]. There are other European companies as ET Technological Institute [21], IRE [22] and MEDI-RADIOPHARMA [23] which provides also radiopharmaceutical products to Portugal.

IBA Molecular, 5 cyclotrons: Madrid, Malaga, Santander, San Sebastian, Sevilla.

99Mo-99mTc Generators - packages

The activity to be transported will depend on the capacity of the generator.
Different packages Type A or Type B(U) can be used, according with the company.

Many hospitals receive a 99Mo-99mTc Generators each week.

99Mo

Type-A package

Type-A package

Type-B(U)

Type-B(U)

99Mo-99mTc Generators - packages

PROCEDIMIENTO 9 . GENERADORES DE MOLIBDENO-99 – TECNECIO-99m

PLIEGO DE PRESCRIPCIONES TÉCNICAS PARA LA CONTRATACIÓN DEL SUMINISTRO DE GENERADORES DE MOLIBDENO-99 – TECNECIO-99m PARA EL HOSPITAL CENTRAL DE LA DEFENSA GÓMEZ ULLA DURANTE EL AÑO 2012

1. El objeto de este lote es el suministro al Servicio de Medicina Nuclear de generadores ^{99}Mo-^{99m}Tc.

2. Los generadores serán entregados, de acuerdo con los pedidos realizados, los lunes antes de las 08:00 horas.

3. La primera elución habrá de proporcionar una actividad entre 1.500 y 1.900 Ci (55,5 y 70,3 GBq) de ^{99m}Tc-Pertecnetato sódico.

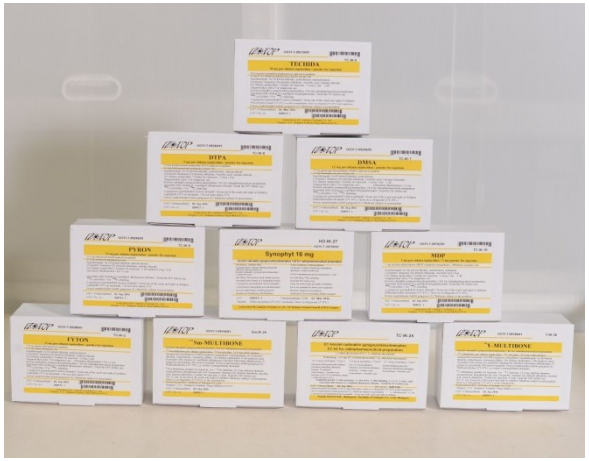
4. Los medicamentos radiofármacos ofertados contarán con todas las autorizaciones pertinentes, estarán legalmente registrados en España y se fabricarán con estricta sujeción a las condiciones fijadas para su autorización y a las prescripciones de las Farmacopeas Española y Europea.

radiopharmaceuticals products

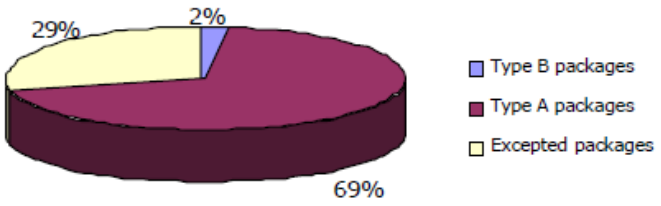
The activity to be transported will be about few kBq.
Usually, the packages used are Excepted package or Type A.

Type-A package

Type-A package



Excepted package



Distribution of packages by type in most countries from EU Member States. packages Type A are the most frequently transported packages, followed by the Excepted packages

Police controls

The drivers are considered as occupationally exposed workers;
In the case of road vehicles, no persons other than the driver and assistants shall be permitted bearing category II-YELLOW or III-YELLOW labels.

Police controls

CSN CONSEJO DE SEGURIDAD NUCLEAR

ACTA DE INSPECCIÓN

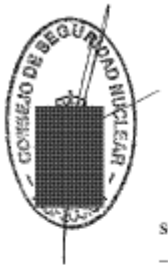
Don [redacted], Inspector acreditado por el Consejo de Seguridad Nuclear para la Comunidad Foral de Navarra,

CERTIFICA:

Que se ha personado, el día once de febrero de dos mil nueve, en el HOSPITAL DE NAVARRA, sito en l[redacted]en PAMPLONA (Navarra).----------

Que la visita tuvo por objeto inspeccionar las condiciones de transporte de unas fuentes radiactivas no encapsuladas, a realizar por parte de la empresa [redacted]----------

Police c[redacted]



- Las fuentes radiactivas, todas ellas de la firma GE HEALTHCARE, S.A. y con destino la Unidad de Radiofarmacia del Hospital de Navarra, objeto del transporte eran las siguientes:
  - Un generador de Molibdeno/Tecnecio de 116.76 GBq de actividad.
  - Una monodosis de Iodo-131 de 729 MBq de actividad.
  - Una monodosis de Iodo-123 de 1.45 GBq de actividad.

- Dichas fuentes eran transportadas como bultos Tipo A, los cuales estaban señalizados con etiquetas de las clases II – AMARILLA (las fuentes de I-123 y I-131) y III – AMARILLA (el generador de Molibdeno/Tecnecio), debidamente cumplimentadas. Que los índices de transporte indicados eran de 0.3 (las fuentes de I-123 y I-131) y 2.1 (el generador de Molibdeno/Tecnecio). Que el nº de Naciones Unidas asignado a todos y cada uno de los bultos era "2915". Que el estado de los embalajes era bueno. Que en el vehículo también se transportaba material no radiactivo.----------

[redacted]

- El transporte era realizado en un vehículo de la marca [redacted] modelo [redacted], con matricula [redacted] el cual se hallaba aparcado próximo a [redacted] del Hospital de Navarra.----------

- Entra la caja y la cabina se encontraba instalada una lámina de plomo. Que los bultos y la carretilla se hallaban sujetos dentro de la caja. Que, según se manifestó, los bultos con mayores índices de transporte se colocan lo más alejados posible del conductor.----------

- El vehículo estaba señalizado, en sus laterales con placas en las que se leía "RADIACTIVE - 7" y en su parte posterior con una placa en la que se leía "RADIACTIVO – 7". Que así mismo disponía, en sus lados frontal y posterior, de las placas de señalización de transporte de materias peligrosas, en las que no se detallaba ningún nº de Naciones Unidas.----------

- El conductor del vehículo disponía de dosímetro personal de termoluminiscencia con nº 11766/4108.----------

Police controls

CSN CONSEJO DE SEGURIDAD NUCLEAR

- Los niveles de radiación máximos medidos en contacto con los bultos y a un metro de distancia fueron los siguientes:
  - Bulto de de Molibdeno/Tecnecio: 310 y 8.5 µSv/h, respectivamente.
  - Bulto de Yodo-123: 100 y 2.6 µSv/h, respectivamente.----------

- Estaba disponible y vigente el "Certificado de Formación" para el transporte de materias peligrosas, clase 7, número [redacted] a nombre del conductor antes citado.---
- Estaban disponibles los siguientes documentos:
  * Carta de Porte.
  * Ficha de seguridad con instrucciones en caso de emergencia.----------

- En la cabina del vehículo se encontraban disponibles dos extintores de incendios de 2 Kg. de peso unitario, un calzo, señales de advertencia, una cinta de balizamiento, un chaleco reflectante para el conductor y una linterna.----------

DESVIACIONES:

- No se detectaron.----------

Que con el fin de quede constancia de cuanto antecede y a los efectos que señala la Ley 15/1980 (reformada por la Ley 33/2007) de creación del Consejo de Seguridad Nuclear, la Ley 25/1964 sobre Energía Nuclear, el Real Decreto 1836/1999 (modificado por el Real Decreto 35/2008) por el que se aprueba el Reglamento sobre Instalaciones Nucleares y Radiactivas, el Real Decreto 783/2001 por el que se aprueba el Reglamento sobre Protección Sanitaria contra las Radiaciones Ionizantes y el Acuerdo Europeo sobre Transporte Internacional de Mercancías Peligrosas por Carretera (ADR), se levanta y suscribe la presente acta por triplicado en Pamplona y en la sede del Instituto de Salud Pública, a once de febrero de dos mil nueve.

TRAMITE.- En cumplimiento de lo dispuesto en el artículo 45 del Reglamento sobre Instalaciones Nucleares y Radiactivas, en este apartado se invita a un representante autorizado de NACIONAL EXPRESS S.A., para que con su firma, identificación, lugar y fecha, manifieste a continuación su conformidad o sus reparos al contenido de la presente Acta.-

CONFORME

NACIONAL EXPRESS S.A.

Radionuclides and radiopharmaceutical products

From IAEA

Conclusions

Safety depends primarily upon the package.

The strict tests to which the packages are submitted and the obedience of Regulations ensure the protection to the man and the environment.

The Regulations are continuously upgraded from experience, advances in technology, changes in the modal transport environments, and socio-political forces.

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