Transportation of Radioactive Material

The BASIC PRINCIPLE Regarding Radioactive Material Transport

EITHER

RESTRICT THE TYPE AND ACTIVITY OF THE RADIOACTIVE CONTENTS

- OR -

PROVIDE ACCIDENT-PROOF PACKAGE DESIGN

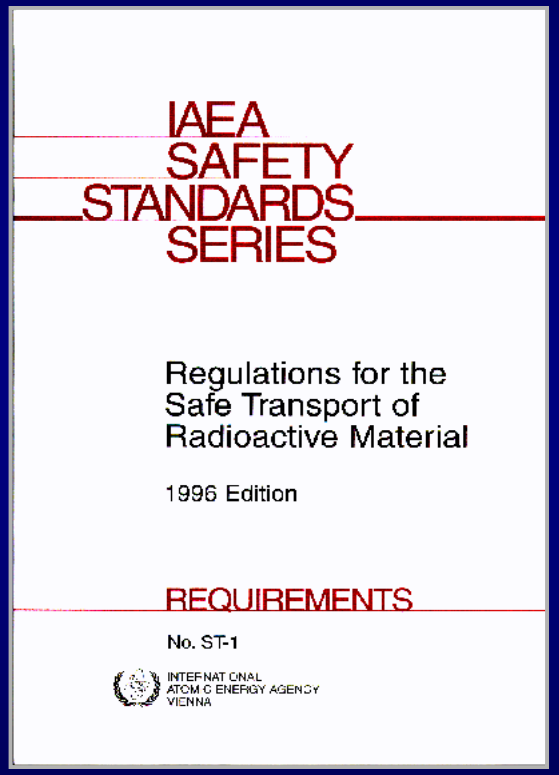
Transportation Regulations

- About 3 million packages of radioactive materials are shipped each year in the US by highway, rail, air, or water. Regulating the safety of these shipments is the joint responsibility of NRC and DOT.
- NRC establishes requirements for the design and manufacture of packages for radioactive materials.
- DOT regulates the shipments while they are in transit, and sets standards for labeling and smaller quantity packages.

Transportation Regulations

- **Basis for Regulations:**

  IAEA Regulations for the Safe Transport of Radioactive Material



- **Domestic Regulations:**
  - **49 CFR 100 – 185, DOT**
  - **10 CFR 71, NRC**
  - **39 CFR, Post Office**

NRC & DOT

- NRC Regulations (10 CFR 71):
  - Type B and Fissile Packages,
  - Transportation Safeguards,
  - Investigates Accidents/Incidents, and
  - Technical Advisor to DOT
- DOT Regulations (49 CFR 170-178):
  - Carriers,
  - Type A & LSA Packages,
  - Issues Certificates of Competent Authority for International Shipments.
- Memorandum of Understanding between NRC and DOT

Controls for Transport

- Transportation regulations prescribe controls to minimize the hazards associated with transporting radioactive materials. These controls include:
  - Conveyance activity limits
  - Use of exclusive use conveyance
  - Transport index and radiation levels
  - Contamination limits
  - Separation and segregation rules
  - Fissile material controls
  - Various hazard communication techniques

The Basic Steps of Radioactive Material Transport

1. Identify
2. Classify
3. Proper Shipping Name
4. Authorized Packaging
5. Hazard Communications
   - Marking and Labeling
   - Documentation
   - Placarding
6. Shipment Controls

What is the radionuclide being shipped?

- Shipping requirements for a given package depend on the specific radionuclides involved, as well as the form of the material.

- The radionuclide is important because the type of radiation emitted by each radionuclide is unique. The radionuclide may emit an alpha particle (e.g. uranium-235), a weak beta particle (e.g. tritium), or a high energy gamma ray (e.g. cobalt-60).

What is the form of the material?

- **Special Form**

  solid material or double encapsulated; must meet rigorous tests to simulate severe accident conditions. These preclude the likelihood of spread of material.

- **Normal Form**

  is not “special form.”

What is the activity of material being shipped?

- **Generally more material may be shipped if it is special form than if it is normal form. See A_1 and A_2 values in 49 CFR 173.435.**

Special Form

Normal Form

§ 173.435 Table of A_1 and A_2 values for radionuclides.

The table of A_1 and A_2 values for radionuclides is as follows:

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) [b]	A_2 (TBq)	A_2 (Ci) [b]	Specific activity (TBq/g)	Specific activity (Ci/g)
Ac-225 (a)	Actinium (89)	8.0×10^{-1}	2.2×10^{1}	6.0×10^{-3}	1.6×10^{-1}	2.1×10^{3}	5.8×10^{4}
Ac-227 (a)		9.0×10^{-1}	2.4×10^{1}	9.0×10^{-5}	2.4×10^{-3}	2.7	7.2×10^{1}
Ac-228		6.0×10^{-1}	1.6×10^{1}	5.0×10^{-1}	1.4×10^{1}	8.4×10^{4}	2.2×10^{6}
Ag-105	Silver (47)	2.0	5.4×10^{1}	2.0	5.4×10^{1}	1.1×10^{3}	3.0×10^{4}
Ag-108m (a)		7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}	9.7×10^{-1}	2.6×10^{1}
Ag-110m (a)		4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}	1.8×10^{2}	4.7×10^{3}
Ag-111		2.0	5.4×10^{1}	6.0×10^{-1}	1.6×10^{1}	5.8×10^{3}	1.6×10^{5}
Al-26	Aluminum (13)	1.0×10^{-1}	2.7	1.0×10^{-1}	2.7	7.0×10^{-4}	1.9×10^{-2}
Am-241	Americium (95)	1.0×10^{1}	2.7×10^{2}	1.0×10^{-3}	2.7×10^{-2}	1.3×10^{-1}	3.4
Am-242m (a)		1.0×10^{1}	2.7×10^{2}	1.0×10^{-3}	2.7×10^{-2}	3.6×10^{-1}	1.0×10^{1}
Am-243 (a)		5.0	1.4×10^{2}	1.0×10^{-3}	2.7×10^{-2}	7.4×10^{-3}	2.0×10^{-1}
Ar-37	Argon (18)	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}	3.7×10^{3}	9.9×10^{4}
Ar-39		4.0×10^{1}	1.1×10^{3}	2.0×10^{1}	5.4×10^{2}	1.3	3.4×10^{1}
Ar-41		3.0×10^{-1}	8.1	3.0×10^{-1}	8.1	1.5×10^{6}	4.2×10^{7}
As-72	Arsenic (33)	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1	6.2×10^{4}	1.7×10^{6}

Activity Examples

- **Carbon-14**
  - A_1 = 40 TBq (1100 Ci)
  - A_2 = 3 TBq (81 Ci)
- **Cobalt-60**
  - A_1 = 0.4 TBq (11 Ci)
  - A_2 = 0.4 TBq (11 Ci)

What is the material being shipped?

- If the material is incorporated in instruments or articles then special limits and regulations apply.
- Similarly, if small quantities of radioactive material are “diluted” in waste (Low Specific Activity or LSA), then less restrictive requirements apply.
- Radioactive material that is “fissile” has special restrictions to avoid criticality.

Identification and Classification

- For DOT, Radioactive Material means any material containing radionuclides where both the activity concentration and the total activity in the consignment exceed certain values specified by DOT.
- Under DOT regulations, the hazard class assigned to radioactive material is Class 7.

Proper Shipping Name

PSN based on shipping category and package type

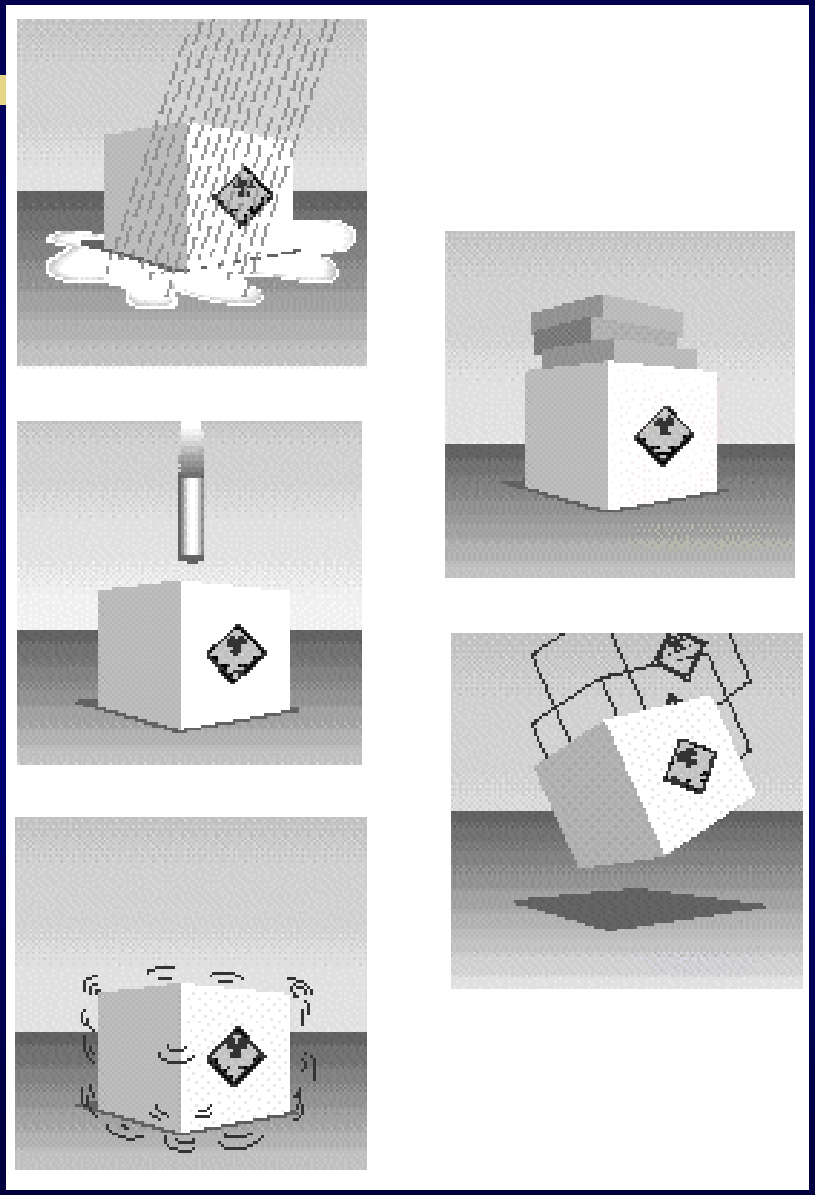
Sym-bols	Hazardous materials descriptions and proper shipping names	Hazard class or Division	Identification Numbers	PG	Label Codes	Special provisions (§172.102)	(8) Packaging (§173.***)		
							Exceptions	Non-bulk	Bulk
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8A)	(8B)	(8C)
I	Radioactive material, excepted package-articles manufactured from natural uranium *or* depleted uranium *or* natural thorium.	7	UN2909	.....	None		422, 426.	422, 426.	422, 426.
D	Radioactive material, excepted package-empty package *or* empty packaging.	7	UN2910	.....	Empty		428	428	428 .....
I	Radioactive material, excepted package-empty packaging.	7	UN2908	.....	Empty		422, 428.	422, 428.	422, 428.
D	Radioactive material, excepted package-instruments *or* articles.	7	UN2910	.....	None		422, 424.	422, 424.	422, 424.
I	Radioactive material, excepted package-instruments *or* articles.	7	UN2911	.....	None		422, 424.	422, 424.	422, 424.
	Radioactive material, excepted package-limited quantity of material.	7	UN2910	.....	None		421, 422.	421, 422.	421, 422.
D	Radioactive material fissile, n.o.s..	7	UN2918	.....	7		453	417	417 .....

Types of Packages

Excepted / IP-1 / IP-2 / IP-3/ Type A		UF_6 / Fissile / Type B / Type C
INCREASINGLY SEVERE TEST		REQUIREMENTS
MAY NOT SURVIVE ACCIDENTS	SURVIVES MINOR ACCIDENTS	SURVIVES SEVERE ACCIDENTS

Type A Package Performance Tests

- Water Spray
- Stacking
- Puncture
- Free Drop
- Vibration



Typical Type A Packages

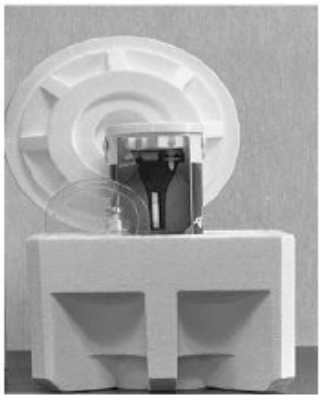


Figure A-Molybdenum 99 Generator

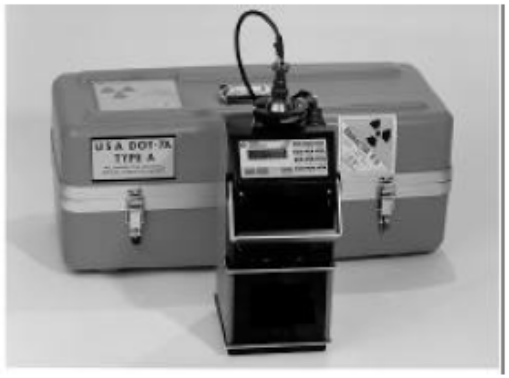


Figure B-Moisture Density Gauge & Carrying Case

Figure C-Steel Drum

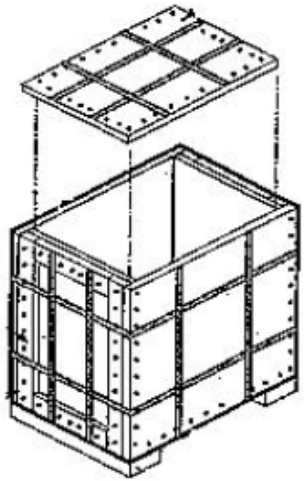
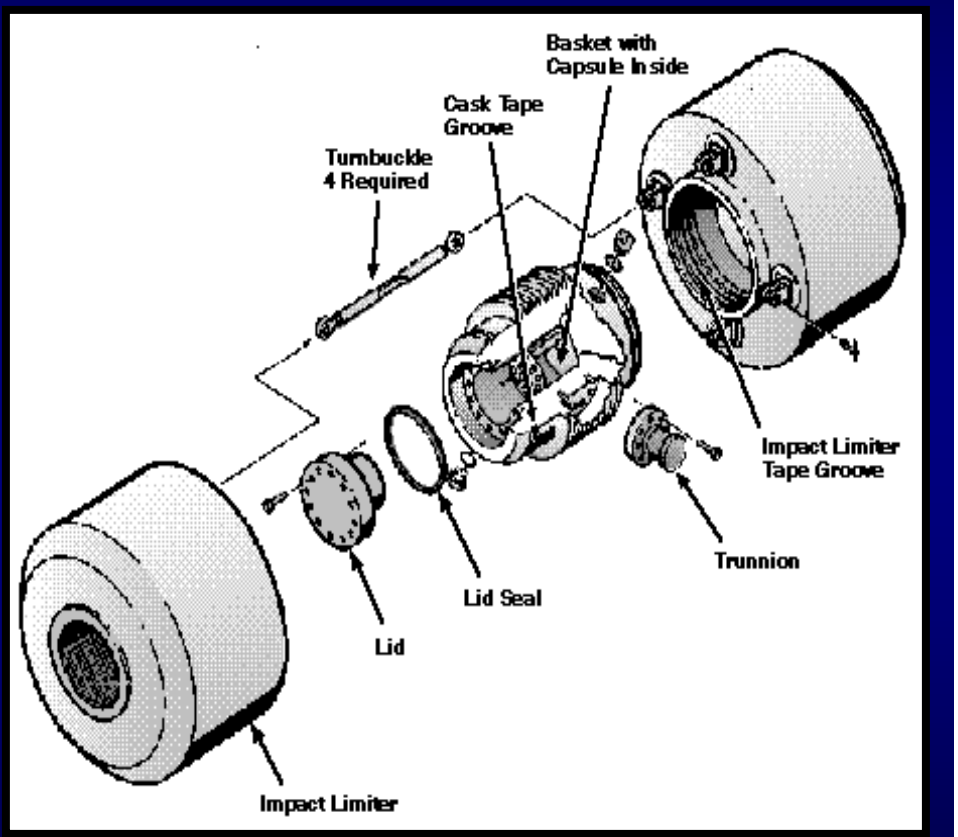


Figure D-Wooden Box

Figure E-Nuclear Pharmacy Unit Dose(s) Package

Type B Packages

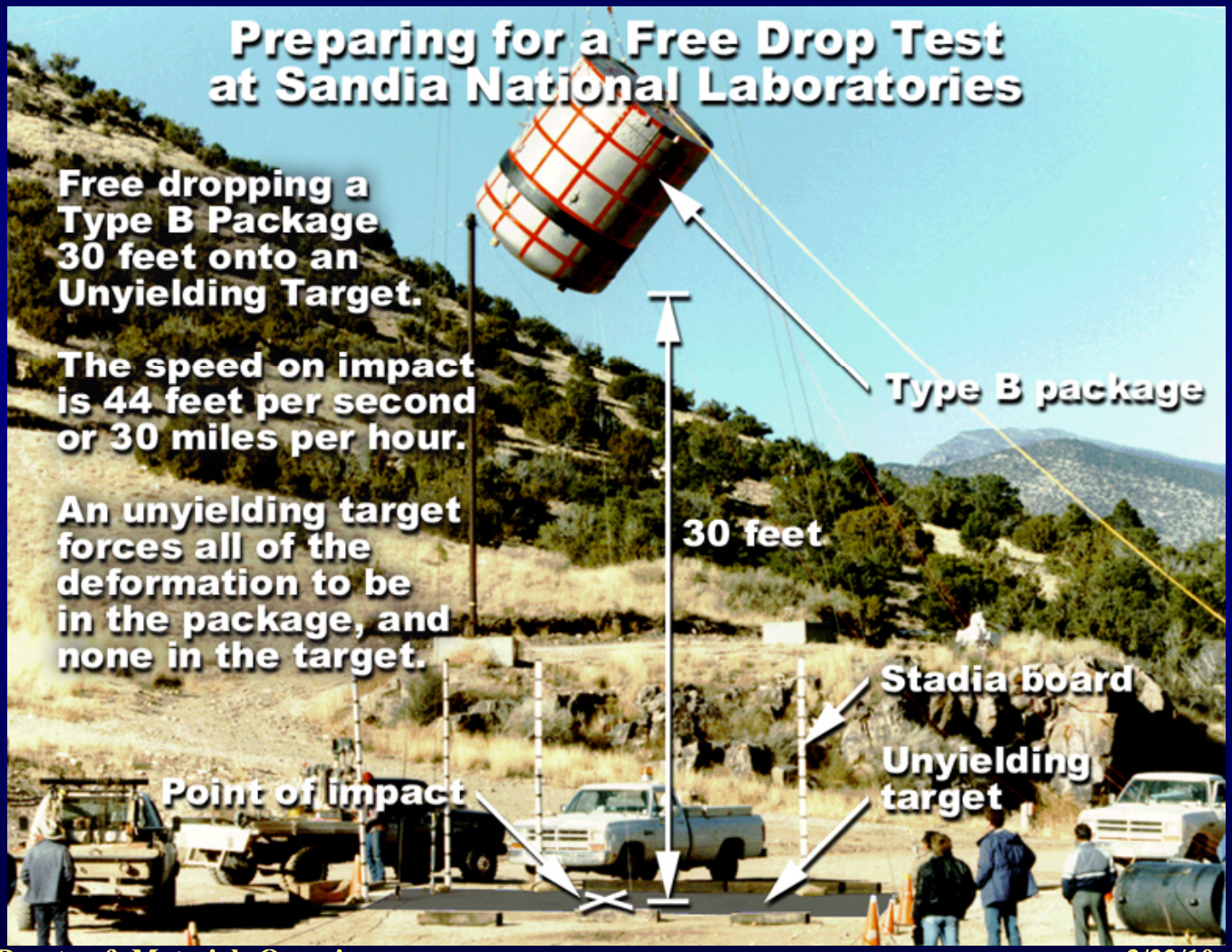
- Designed to survive the most severe accidents
- Design requirements must meet the DOT Type A package requirements plus additional NRC requirements



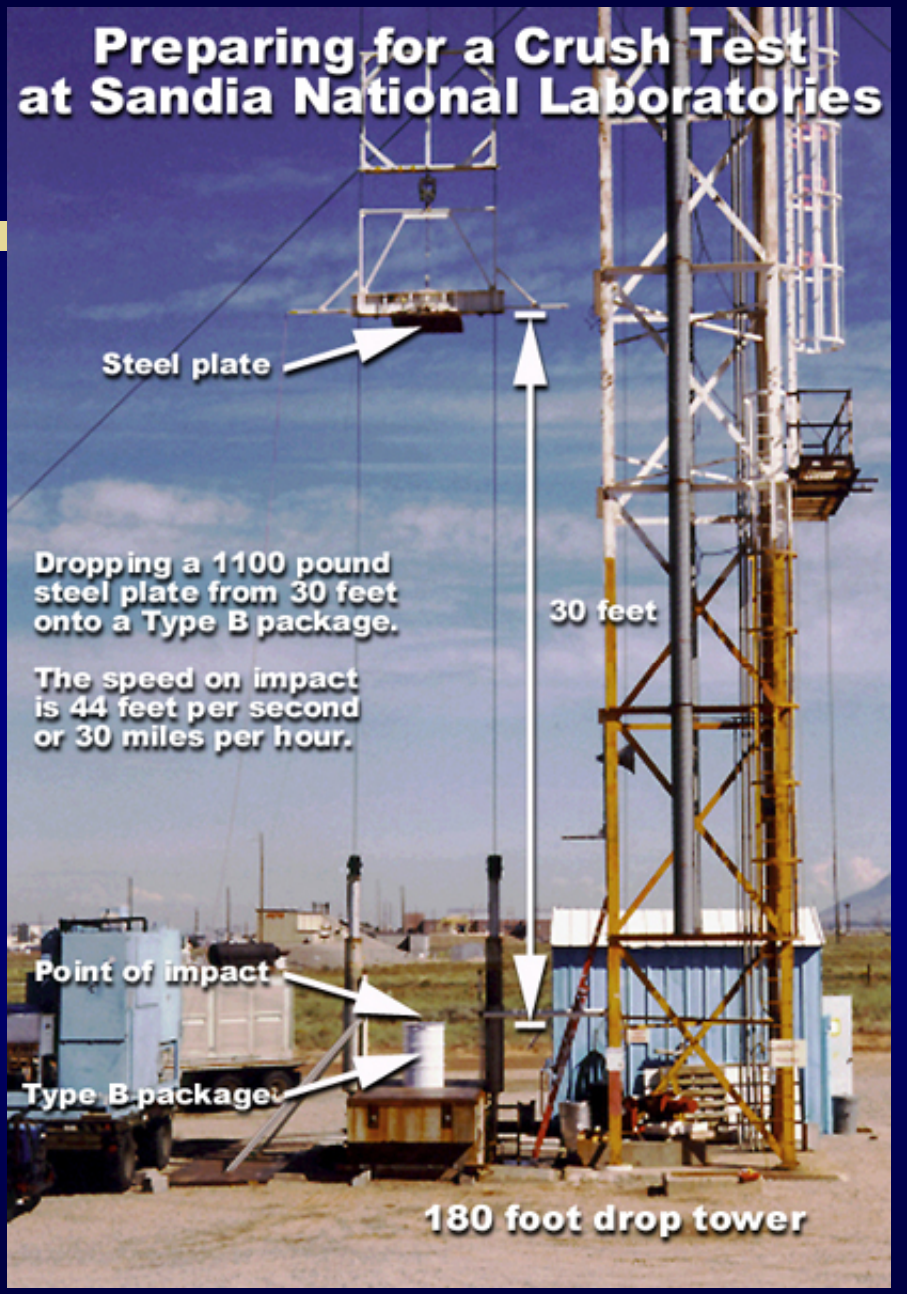
Type B Package Testing

- 10 CFR 71.73 requires that Type B shipping containers survive hypothetical accident conditions for free drop, crush, puncture, thermal, and immersion scenarios. These test are to be conducted in a certain sequence.

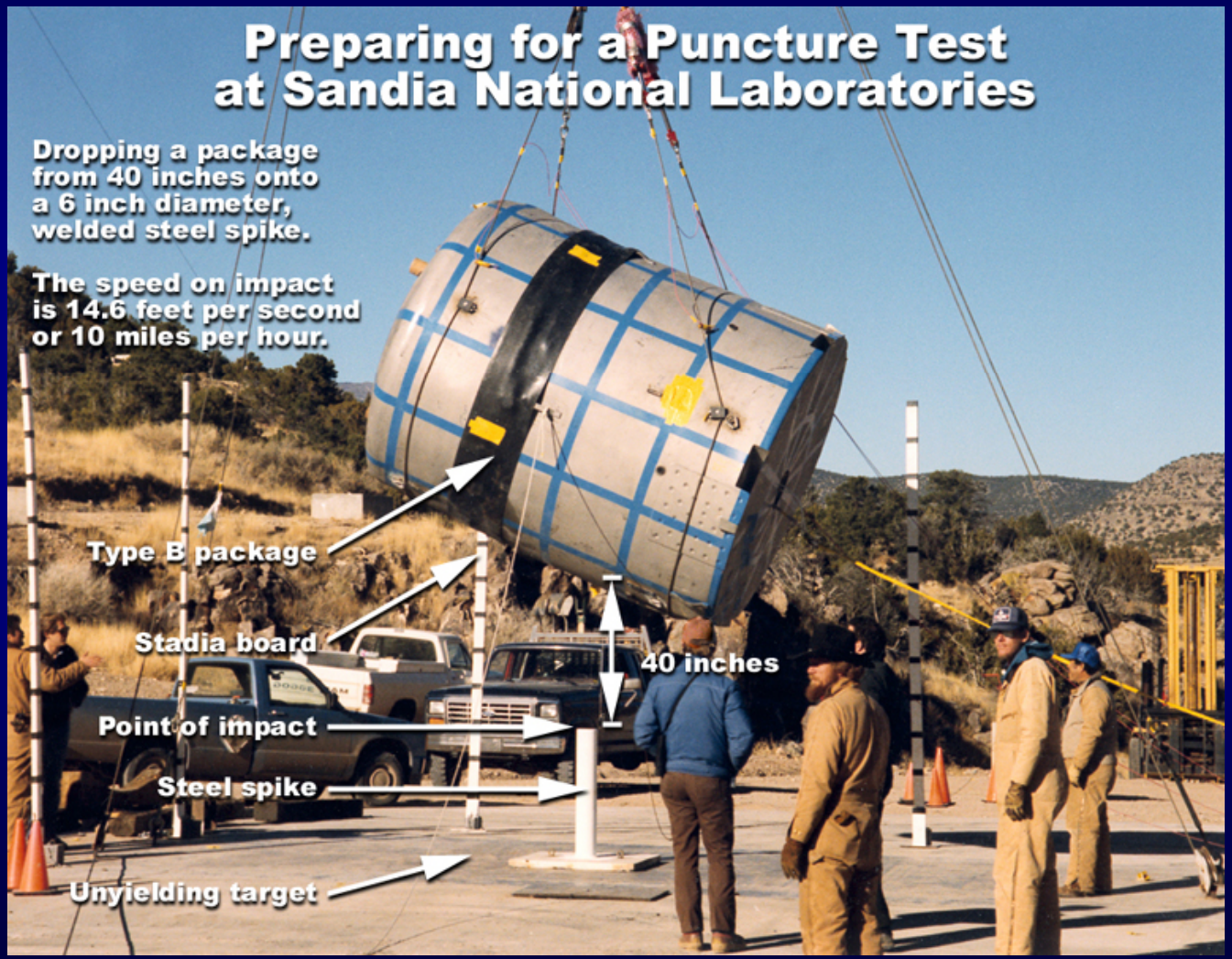
Drop Test


Preparing for a Free Drop Test
at Sandia National Laboratories
Free dropping a
Type B Package
30 feet onto an
Unyielding Target.
The speed on impact
is 44 feet per second
or 30 miles per hour.
An unyielding target
forces all of the
deformation to be
in the package, and
none in the target.
Type B package
30 feet
Stadia board
Unyielding
target
Point of impact

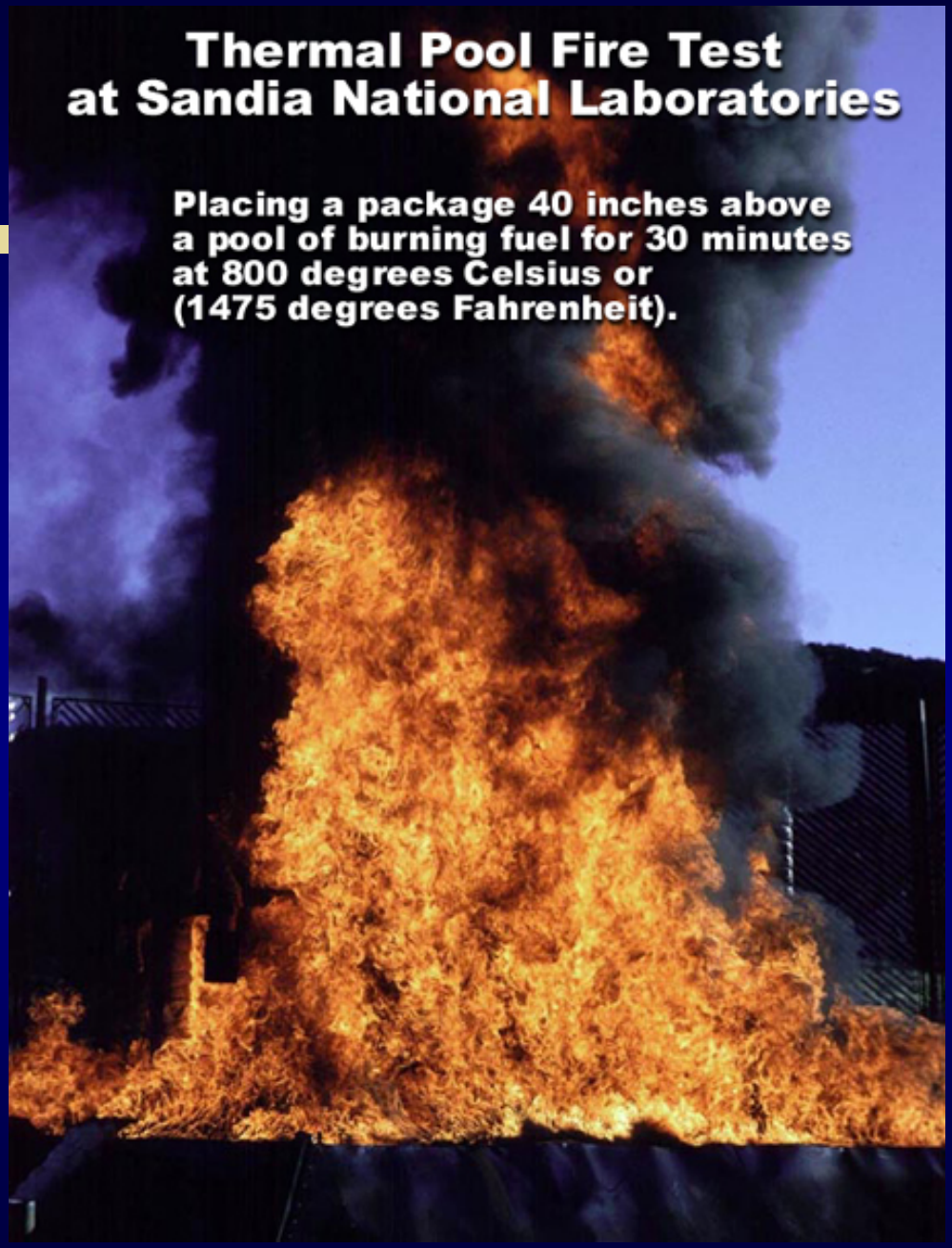
Crush Test


Preparing for a Crush Test
at Sandia National Laboratories
Steel plate
Dropping a 1100 pound
steel plate from 30 feet
onto a Type B package.
The speed on impact
is 44 feet per second
or 30 miles per hour.
30 feet
Point of impact
Type B package
180 foot drop tower

Puncture Test



Fire Test


Thermal Pool Fire Test
at Sandia National Laboratories
Placing a package 40 inches above
a pool of burning fuel for 30 minutes
at 800 degrees Celsius or
(1475 degrees Fahrenheit).

Immersion Test

[redacted]

Preparing for an Immersion Test at Sandia National Laboratories

Placing a packaging in a pressure vessel simulating 50 feet under water for 8 hours.
Fissile materia packagings are also immersed under 3 feet of water for 8 hours.
This regulatory test is performed sequentially after the "Hypothetical Accident Conditions" 1 through 4.

Type B Package Test Criteria

- Radiation level at 1 m from the package ≤10 mSv/hr
- After Normal Conditions same as Type A package except:
  - Loss of radioactive content restricted to ≤10^{-6} A_2/hr
- After Accident Conditions
  - Accumulated loss of radioactive content restricted to ≤A_2 for one week

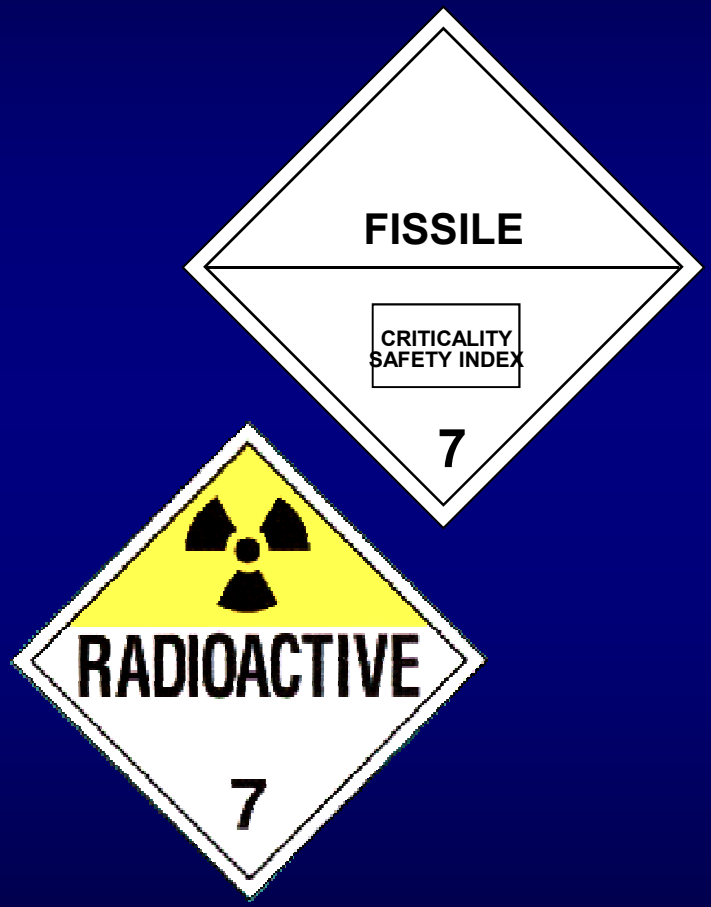
Hazard Communications

The regulations require that the hazards posed by the consignment are clearly communicated to all parties concerned to facilitate:

- **Complete radiation protection at all phases**
- **Correct emergency response for accidents**

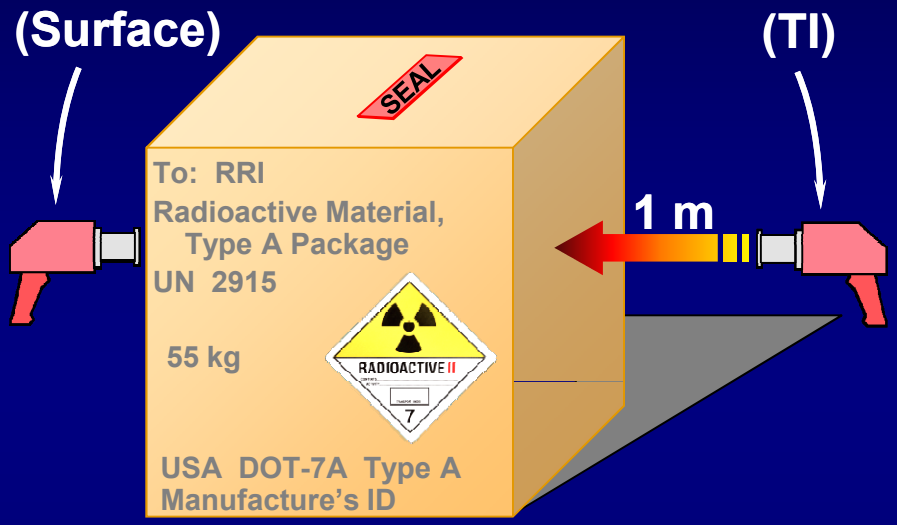
Hazard Communications

- **Hazard communications are accomplished by:**
  - **Marking material and packages**
  - **Labels on packages**
  - **Placards on freight containers, tanks, road and rail vehicles**
  - **The transport documents**
  - **Emergency response information**



Labeling Categories

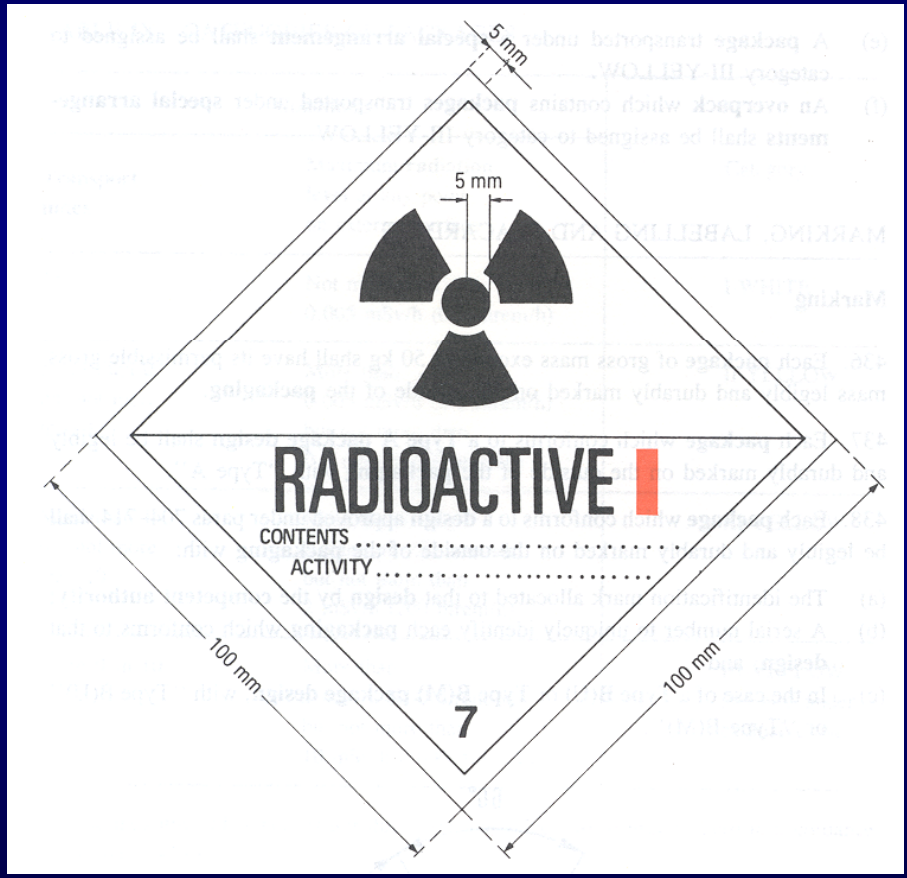
- Radioactive White-I
- Radioactive Yellow-II
- Radioactive Yellow-III



- Selection of appropriate label is based on surface radiation levels and Transport Index (TI) of package
- The TI is the dose rate at one meter from the package

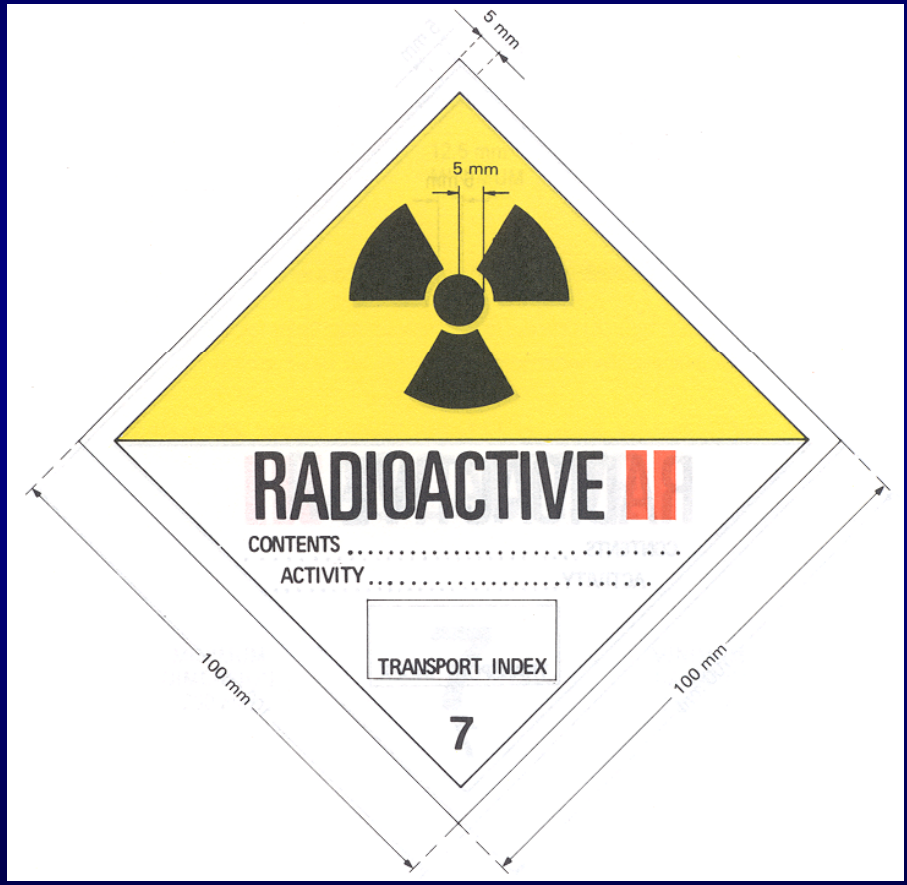
White I

- TI = “0” at 1 meter (< or = 0.05 is considered 0)
- Dose rate on contact does not exceed 0.5 mrem/hour.



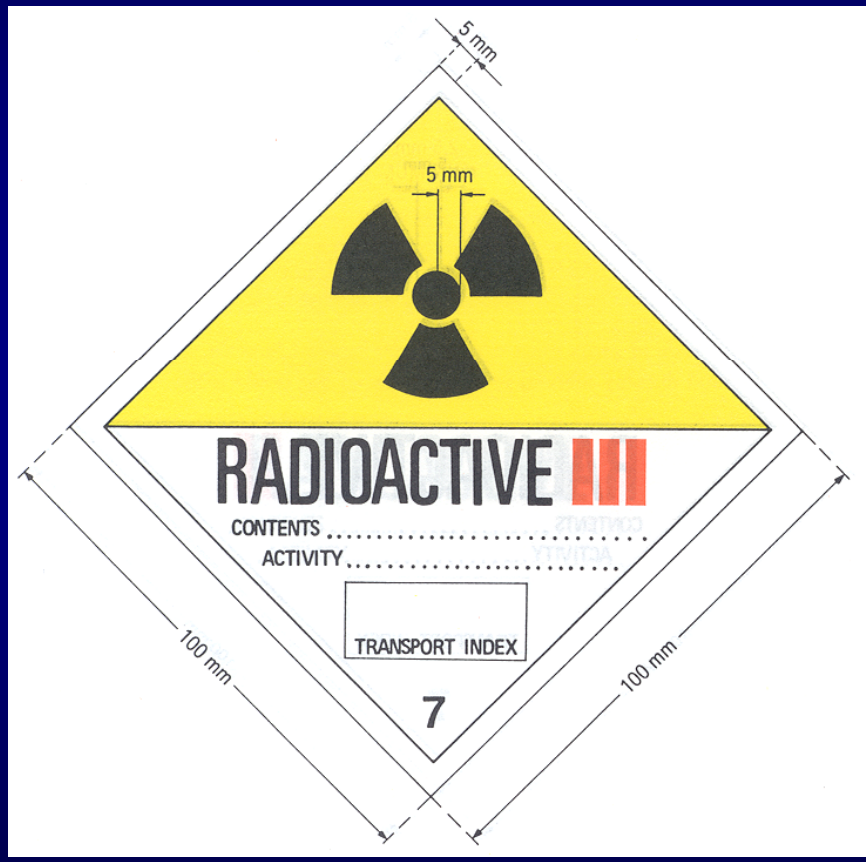
Yellow II

- TI is greater than 0, but less than or equal to 1.
- Dose rate on contact exceeds 0.5 mrem/hour but is less than or equal to 50 mrem/hour.



Yellow III

- TI is greater than 1 but less than or equal to 10.
- If TI > 10, must be shipped as “exclusive use”
- Dose rate on contact is > 50 mrem/hour but not over 200 mrem/hour.



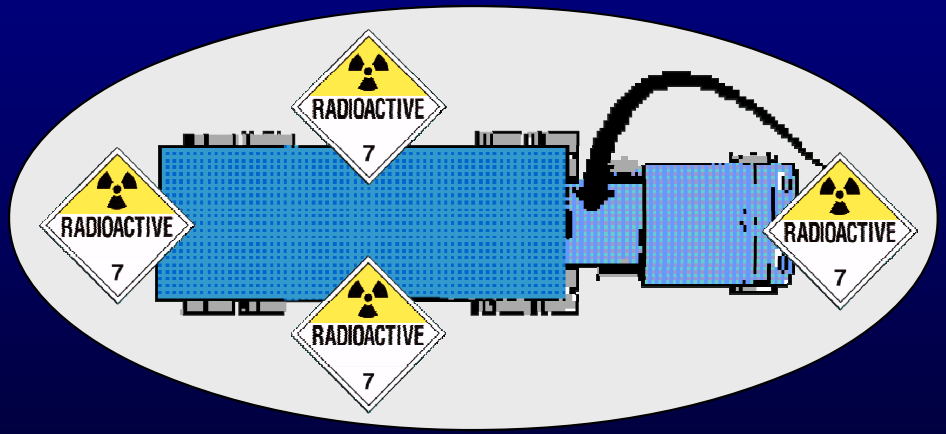
Placarding

- Activity > 3,000 x A_1 or > 3,000 x A_2 OR > 1,000 TBq, whichever is least
- Yellow III labels
- Highway Route Control Quantity
- Type B Packaging

Placard Determination for Radioactive Material

- Rad Yellow-III labeled packages
- LSA material and SCO consigned as Exclusive Use per 173.427(a)(6)

- Highway route controlled quantity placard
- UF_6 subsidiary hazard (8) if >454 kg



49 CFR 172.504; 172.505(b); 172.516

Non-Exclusive Use

- Dose rate not to exceed 200 mrem/hr on contact
- TI not to exceed 10
- Total TI not to exceed 50

Exclusive Use
Open Transport

- Dose rate not to exceed 200 mrem/hr on surface of package.
- Dose rate in cab not to exceed 2 mrem/hr.
- Dose rate not to exceed 10 mrem/hr at 2 meters from vehicle.

Exclusive Use
Closed Transport

- Dose rate not to exceed 200 mrem/hr on contact w/outside of trailer or 1000 mrem/hr on package.
- Dose rate in cab not to exceed 2 mrem/hr.
- Dose rate not to exceed 10 mrem/hr at 2 meters from vehicle.

Transportation Case Study: Industrial Radiography

- The radiography camera is a Type B(U) shipping container.
- This radiography camera was involved in a car fire. The source remained shielded and intact.

Want More?

H-308, "Transportation of Radioactive Materials," is a week long course covering NRC and DOT shipping requirements.

THE END