What Every Certified Health Physicist Should Know About Transportation of Radioactive Material

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The basics

- Keep doses ALARA
- How?
  - Time, Distance, Shielding, Containment
- Training
- Governmental legislation and regulations, competent authority to inspect and enforce regulations

The basics

- Primary reliance on package design and preparation (Containment)
- Operational controls – e.g., routing, exclusive use, special arrangements (permits)
- Hazard communication

The basics

- Emergency response
- Management system
- Compliance assurance
- Non-compliance
- Special arrangement

Dose limits

- Basic dose limits – Not practical for transportation
- Secondary or derived limits
  - Radiation protection examples: ALI, DAC
  - Transportation: A_1, A_2, contamination and radiation level, segregation limits (transport index)

Basic Radionuclide values

A_1, A_2, EXEMPTION VALUES, SPECIAL CATEGORIES

A_1 and A_2 values

- Activity limits for Type A packages
- Derived on basis of radiological consequences in event of failure of the package
- Doses deemed to be acceptable
- Shipments with activity exceeding A values require use of Type B packages

§ 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}

A_1 and A_2 values

- Derived using the "Q" system (quantity, dose)
  - Q_A – External photon
  - Q_B – External beta
  - Q_C – Inhalation
  - Q_D – Skin and ingestion
  - Q_E – Submersion
- Dose to person exposed in vicinity of accident will not exceed
  - 50 mSv (5 rem)
  - 0.5 Sv (50 rem) to organ
  - 0.15 Sv (15 rem) to lens of eye
- Person unlikely to remain at 1 m from package for more than 30 minutes

A_1 and A_2 values

- A_1
  - Derived from lesser of Q_A and Q_B
- A_2
  - Least of all Q values

- A_1 represents the maximum activity of **special form** material allowed in Type A package
- A_2 represents the maximum activity of **normal form** material allowed in Type A package

Example A_1 and A_2 values

Radionuclide	A_1 (TBq)	A_1* (Ci)	A_2 (TBq)	A_2* (Ci)
H-3	40	1,080 (1.1×10^3)	40	1,080 (1.1×10^3)
Cs-137	2	54	0.6	16.2 (1.6×10^1)
Ra-226	0.2	5.4	0.003	0.081

*-Unofficial value

Exemption values

- Concentration limits
- Total activity limits for consignments
- If the shipment contains RAM not above one of these limits, it is exempt from transport regulations
- Individual effective dose: 10 μSv (1 mrem) in a year
- Collective dose: 1 person-Sv in a year
- Assumes normal transport conditions

Exemption values

- Activity concentration values apply to materials in a package or in or on a conveyance; assumes homogenous mixture
- Total activity exemption values apply to a consignment
  - Accounts for all radioactive material present, not just in a single package

Example exemption values

Symbol	Activity Concentration (Bq/g)	Activity Concentration (Ci/g)*	Activity Limit for Exempt Consignment (Bq)	Activity Limit for Exempt Consignment (Ci)*
H-3	1×10^{6}	2.7×10^{-5}	1×10^{9}	2.7×10^{-2}
Cs-137	1×10^{1}	2.7×10^{-10}	1×10^{4}	2.7×10^{-7}
Ra-226	1×10^{1}	2.7×10^{-10}	1×10^{4}	2.7×10^{-7}

*-Unofficial value

Low specific activity material

- Low concentration
- A form such that an average specific activity may be assigned to it
- Degree of uniformity varies depending on category

LSA-I

- May be shipped unpackaged or in industrial packages
  - U, Th ores and concentrates
  - Ores containing other NORM
  - Natural U, DU, Nat, Th, unirradiated
  - Radioactive material with unlimited A_2
  - Other RAM where concentration ≤30× Exempt concentration values

LSA-II

- Higher concentrations of radioactive material
- Materials may not be uniformly distributed
- Material may be present for intake after an accident
- Water with tritium concentration up to 0.8 TBq/L (20.0 Ci/L)
- Other radioactive material in which the activity is ***distributed throughout*** and the average specific activity does not exceed 10^{-4} A_2/g for solids and gases, and 10^{-5} A_2/g for liquids

LSA-III

- Concentration of RAM 20 times higher than LSA-II
- Material is ***essentially uniformly distributed***
- Higher concentration justified by
  - Solid material only
  - Leaching test to demonstrate insolubility of material when exposed to weather conditions
  - Stronger packaging required

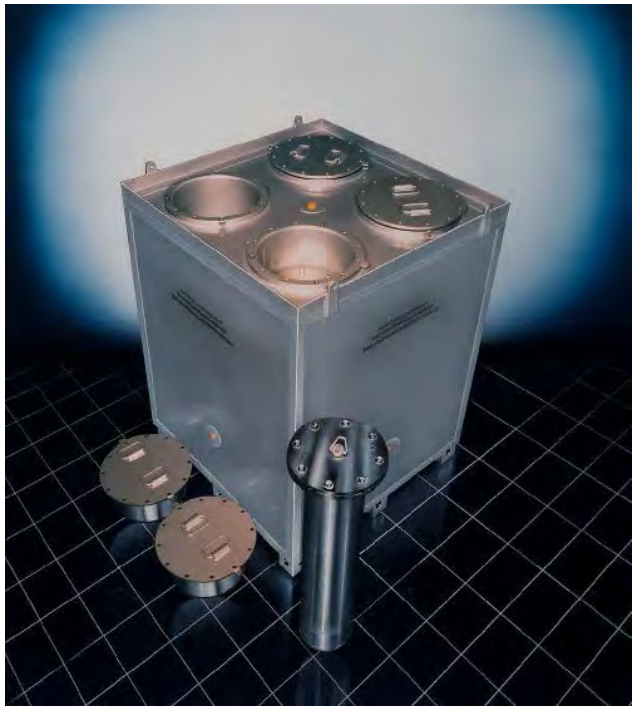
Surface contaminated objects

- **SCO-I**
  - May be shipped unpackaged or in Type IP-1 packaging
- **SCO-II**
  - Shipped in Type IP-2 packaging

- Fixed and non-fixed contamination limits
- Derived on accident scenario
  - All non-fixed contamination released
  - 20% of fixed contamination released
- Packaging requirements and contamination limits provide level of safety equivalent to Type A

Fissile material

- Criticality safety
- Approved fissile material packages required
- Fissile material exceptions



Uranium hexafluoride

- Package design
- UF_6 must be in solid form
- Package volume limits
- Package below atmospheric pressure when offered for transport
- Excepted package option for mass <0.1 kg/package

Packaging

Package type is important when considering accident conditions

Package Type – Containment

- Type
  - Excepted
  - Industrial
  - Type A
  - Type B(U), Type B(M)
  - Type C (not authorized in U.S.)

Requirements for control and transport

- Contamination and leakage
- Main exposure pathways are skin irradiation and ingestion and inhalation of re-suspended material
- Most hazards material commonly transported considered when establishing limits
  - Sr-90, Ra-226, Pu-239

Contamination limits [see 49 CFR 173.443]

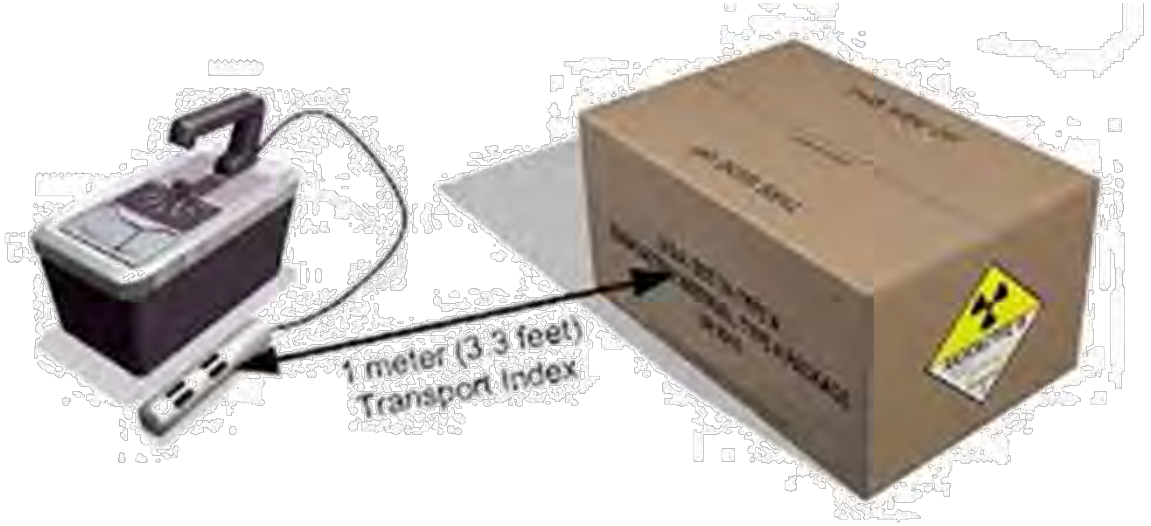
- Non-fixed contamination must be as low as reasonably achievable (ALARA)
  - Applies to exterior of package, and
  - Interior of conveyances/freight container/ overpack containing packages of Class 7 material
- When surveying for non-fixed contamination, wipe an area of at least 300 cm^2 with absorbent material, analyze wipe sample prior to shipment (other methods may be used)
- Check areas likely to be contaminated
- Wipe efficiency of 0.1 (10%) may be used unless otherwise known

Contamination control [49 CFR §173.443(e)]

- If a package or conveyance is or suspected to be leaking,
  - Restrict access to the package or conveyance, and
  - Assess, as soon as possible, the extent of contamination and the resultant radiation level of the package or conveyance
- Check the package, the conveyance, the adjacent loading and unloading areas, and, if necessary, all other material which has been carried in the conveyance

Requirements for control and transport

- Transport index (TI)
- Maximum dose rate at 1 m from package, in mSv/h multiplied by 100 (mrem/h)



- Basis for carrier segregation of packages, and limit exposure of members of public and transport workers

Requirements for control and transport

- Radiation level limits at surfaces
  - Considers doses to worker, public and film
- Criticality safety index
  - Limiting accumulation of packages containing fissile material
  - See 10 CFR 71.22, 71.23. and 71.59

Requirements for control and transport

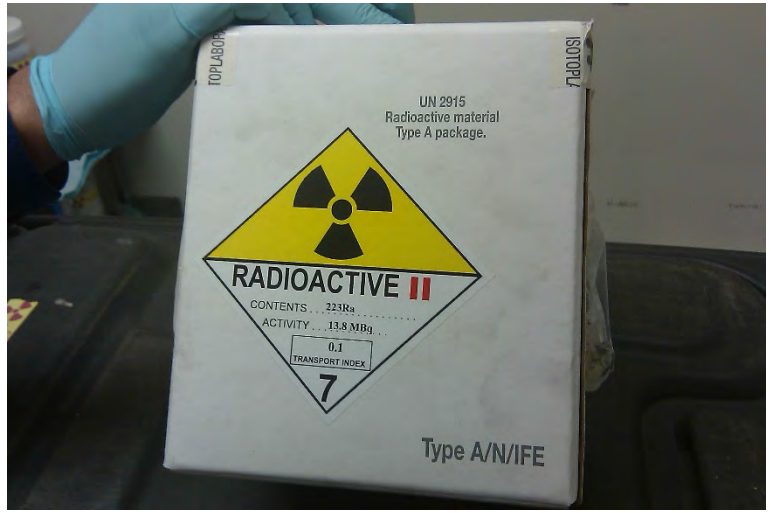
- Exclusive use
- Relaxation of normal transport requirements
- Additional controls in place to assure safety
  - Lower packaging requirements for LSA/SCO
  - Higher dose rates from packages
  - Higher CSI for fissile shipments

Requirements for control and transport

- Labels
  - Packages assigned to a category
- Markings
  - Affixed to outside, durable
- Placards

Package category – Hazard Communication

- Routine transport consideration
- Label
  - White-I – Handled with no restrictions
  - Yellow-II, Yellow-III – dose assessment necessary, with segregation, dose limits, constraints considered



Labeling [§172.403]

Label	Surface Radiation Levels [mSv/h (mrem/h)]	TI
White I	Up to 0.005 (0.5)	0
Yellow II	>0.005 – 0.5 (0.5-50)	>0 - 1.0
Yellow III	>0.5 – 2 (50-200)	>1 -10
Yellow III (Exclusive Use)	>2 – 10 (200-1000)	>10

Markings

- Convey information in event of loss of control of package
  - Consignor/consignee
  - UN number (aids in emergency response)
  - Proper shipping name
  - Mass (if >50 kg), to aid in assuring proper handling
  - Package type

Placards

- Displayed on large freight containers, tanks, rail cars, road vehicles
- Displayed on all four sides
- Display on white panel with black border (Highway route controlled quantity)

Hazard communication

- Display of labels, markings, placards not required for all shipments
- Depends on package type
- Whether shipped exclusive use or not
- Package size

Conclusion

- Questions/Comments
- Contact

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