SAND2011-2086P

Defense Nuclear Nonproliferation

Source Information Requirements for Transportation 15-Part B

Search and Secure Workshop

Source Information Requirements for Transportation

- Source information required for movement
  - Nuclide
  - Activity
  - Form of source/device
  - Dose rates
- Determined from field identification

Specific Radiological Data Required

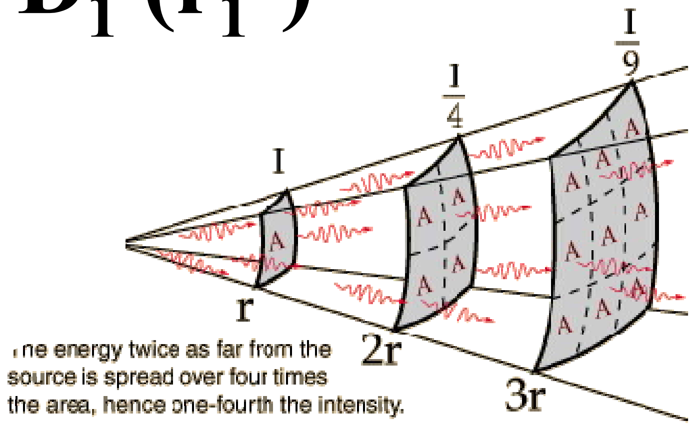
- Dose rate at contact with package or overpack
- Dose rate at 1 m from package or overpack
- Dose rate at 2 m from plane of vehicle (for exclusive use only)

Inverse Square Law
Use of Measured Data

- Dose rates changes with distance

$$D_2\,(r_2^{\,2}) = D_1\,(r_1^{\,2})$$

D_1 = Measured dose rate at distance r_1
D_2 = Dose rate at distance of interest r_2



- **Examples:**

  D_1 = Dose rate at 1 m = 1 mSv/h (100mrem/h)
  D_2 = Dose rate at 2 m = 0.25 mSv/h (25 mrem/h)
  or D_3 = Dose rate at 3 m = 0.111 mSv/h (11.1 mrem/h)

Use of Gamma Ray Constants to Estimate Activity

Nuclide	rem/hr/Ci @ 1m	mSv/hr/MBq @ 1m
Co-60	1.37	3.7×10^{-4}
Cs-137	0.35	1.0×10^{-4}
Ra-226*	1.0	3.3×10^{-4}
Am-241	0.02	8.5×10^{-5}

* = in equilibrium with daughters

Calculate expected dose rate from a source

Find dose rate at 1 meter from 3,700 GBq of Co-60?

Formula: Dose rate = (Gamma Ray Constant) X (Activity)
or D=G X A

D= Dose rate G= Gamma Ray Constant A=Activity

G = Gamma Ray Constant Co-60 = 3.7 x10^{-4} mSv/h/ MBq @ 1 meter

A = 3,700 GBq = 3,700,000 MBq Find D=?

Calculation

D = (3.7 x 10-4 mSv/hr/MBq) x 3.7x10^{6} MBq =

D = 1.37 x 10^{3} mSv/hr for 3,700 GBq Co-60 at 1 meter

Calculate expected dose rate from a source

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Find dose rate at 1 meter from 100 Ci of Co-60?

Formula: Dose rate = (Gamma Ray Constant) X (Activity)

or D = G X A

D= Dose rate G= Gamma Ray Constant A=Activity

Gamma Ray Constant Co-60 = 3.7x10-4 mSv/hr/MBq

GCR_{Co-60} = $3.7x10^{-4}$ mSv/hr/MBq x (0.1 rem/mSv) x $3.7x10^{4}$ MBq/Ci

GCR_{Co-60} = 1.37rem/hr/Ci @ 1 meter

A = 100 Ci Find D=?

Calculation

D = (1.37 rem/hr/Ci) x (100Ci) = 137 rem/h@1 meter for 100 Ci Co-60

Calculate Activity from a Dose Rate

Given a 1 mSv/h dose rate at 1 meter from a Cs-137 source, estimate the activity of the source in MBq?

Formula: **Dose rate = (Gamma Ray Constant) X (Activity)**

or D=G X A or A=D/G

G= Gamma Ray Constants Cs-137 = 1.0 x 10^{-4} mSv/h per MBq at 1 meter

Given D= 1 mSv/h at 1 meter A=?

Calculation

A = (1 mSv/hr)/(1.0 x 10^{-4} mSv/hr/MBq) = 1.00 x 10^{4} MBq

Answer: Activity = A = 1.0 x 10^{4} MBq= 10 GBq

Calculate Activity from a Dose Rate

Given a 100 mrem/h dose rate at 1 meter from a Cs-137 source, estimate the activity of the source in Ci?

Formula: Dose rate = (Gamma Ray Constant) X (Activity)
or D=G X A or A=D/G

G= Gamma Ray Constants Cs-137 = $1x10^{-4}$ mSv/hr/MBq@1 m
G_{Cs-137} = $1x10^{-4}$ mSv/hr/MBq@1 m x ($1x10^{2}$ mrem/mSv) x $3.7x10^{4}$ MBq/Ci
G_{Cs-137} = 370 mrem/Ci @ 1 m

Given D= 100 mrem/h at 1 meter A=?

Calculation

A = 100 mrem/hr/ 370 mrem/hr/Ci @ 1 m

Answer: Activity = A = 0.27 Ci

Shielding – Use of HVL and TVL

- **HVL – (Half Value Layer)** thickness of material required to reduce dose rate by a factor of 2

- **TVL – (Tenth Value Layer)** thickness of material to reduce dose rate by a factor of 10

D_2 =shielded dose rate

D_1= unshielded dose rate

n = # half value layers = $\dfrac{\text{material thickness}}{\text{1/2 or 1/10 value thickness}}$

Equations for half/tenth values

$$D_2 = \frac{D_1}{2^n}$$

$$D_2 = \frac{D_1}{10^n}$$

HVLs and TVLs

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Nuclide	HVL & TVL	Concrete (2.5 g/cm^3) (cm)	Lead (11.3 g/cm^3) (cm)
Co-60	HVL TVL	6.2 20.6	1.20 4.0
Cs-137	HVL TVL	4.8 15.7	0.65 2.1
Ir-192	HVL TVL	4.3 14.7	0.6 2.0
Ra-226	HVL TVL	6.9 23.4	1.66 5.5

Ref.: NCRP Report 49 (1976), p. 89, Table 28 Selected Gamma Ray Sources

Use of HVLs and TVLs

Problem

A drum is to be shipped on a non-exclusive use vehicle and it contains sources of Co-60 which are resulting in a reading of 4.7 mSv/h on contact with the external surface of the drum.

How many cm's of lead would be required to reduce this level to the limit for radiation levels on the external surface of the package? How many cm's of concrete?

Use of HVLs and TVLs

Solutions

Transportation Limit for contact dose rate on the package is 2.0 mSv/h

Formula: HVL calculation $D_2 = (D_1)/(2^n)$

HVL for lead = 1.2 cm

HVL for concrete = 6 cm

D_2 = Shielded dose rate = 2.0 mSv/hr

D_1 = Unshielded dose rate = 4.7 mSv/hr

n = Number of HVL's required

Calculation: $2^n = D_1/D_2$

$n (\log 2) = \log (D_1/D_2)$

$n = (\log ((D_1/D_2))/ \log 2$

n = 1.23 HVL

LEAD required (cm): = (1.23 HVL)x (1.2 cm lead/ HVL) = 1.48 cm lead

Field approximations – 1 HVL reduces to 2.35, so 2 HVL required to go below 2 mSv/h

How many cm of concrete?

CONCRETE: using 6 cm for concrete = (1.23 cm HVL concrete) x (6 cm concrete/HVL)

= 7.4 cm concrete

Field approximations – 1 HVL does not reduce it enough so ~2 HVL required to go below 2 mSv/h

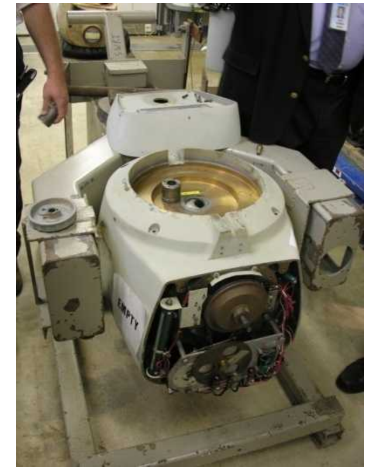
Conclusion ~2 HVL of lead or concrete is needed to legally ship this source.

Field Characterization: Device/Source Information

- **Device Information**
  - Device manufacturer
  - Model type or number
  - Serial number
  - Isotope
  - Activity
  - Date of manufacture
  - Physical shape and dimensions
  - Documentation on the device (IAEA, USNRC, other)
    - Original shipping papers
    - Manufacture's device specifications
    - Special form certification
- **Measurements – Isotopic, dose rate and contamination levels**
- **Provides information for determination of packaging / transportation / disposition requirements**

Field Identification

Medical Use



Field Identification

Radiography

Field Identification

Moisture/Density Gauges

Field Identification

Level/Density/Flow Gauges

Field Identification

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Hydrology

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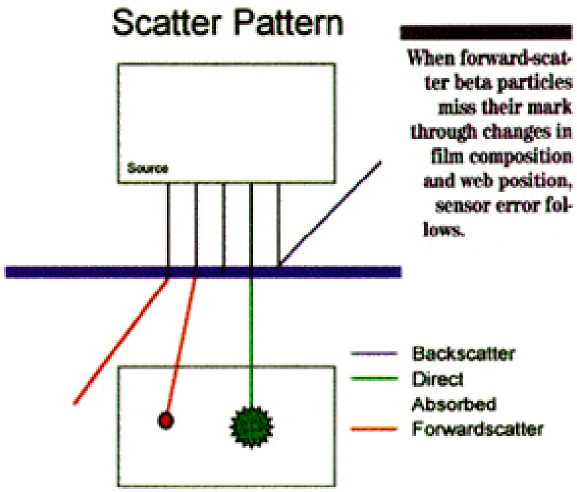
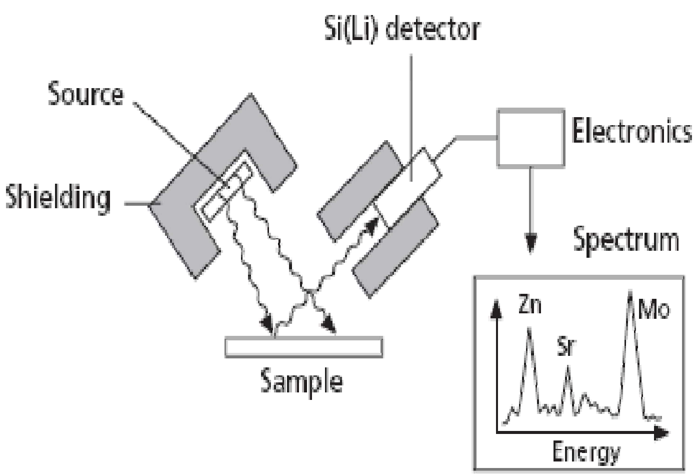
Field Identification
Thickness Gauges



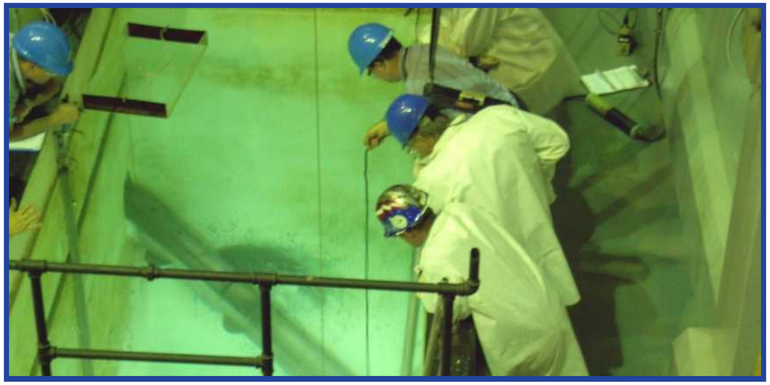
Field Identification

X-Ray Fluorescence Devices



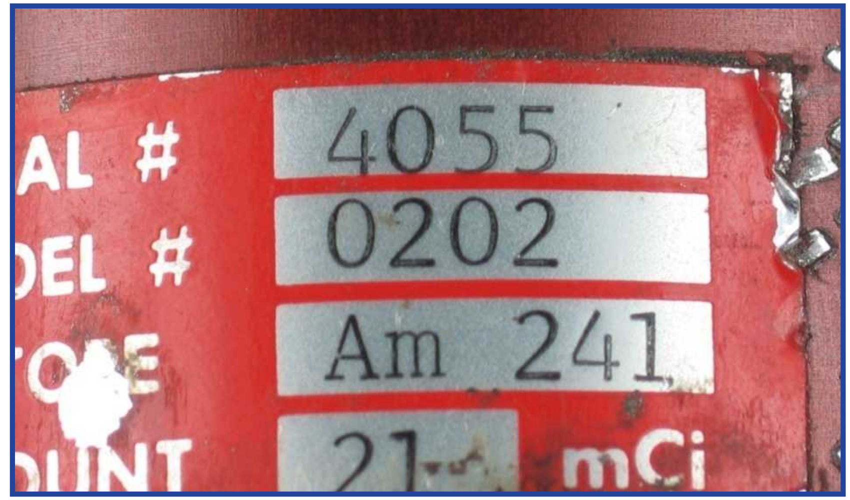
Field Identification

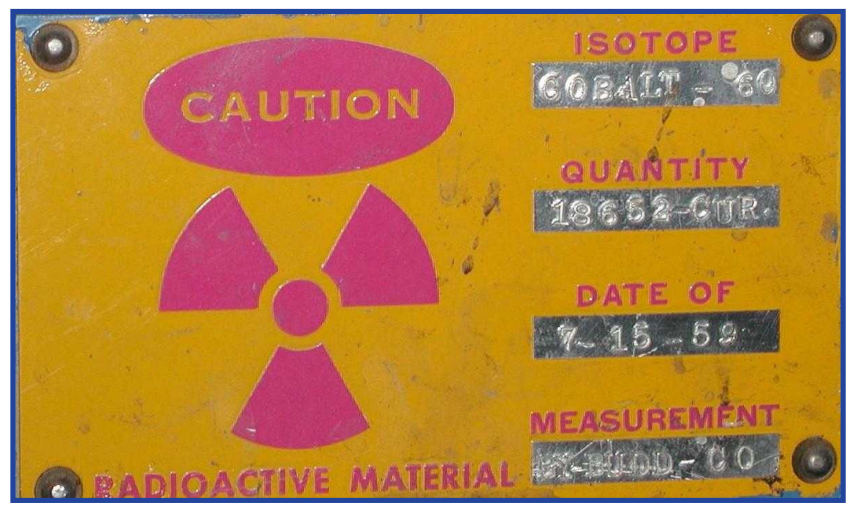
Irradiators



Field Characterization

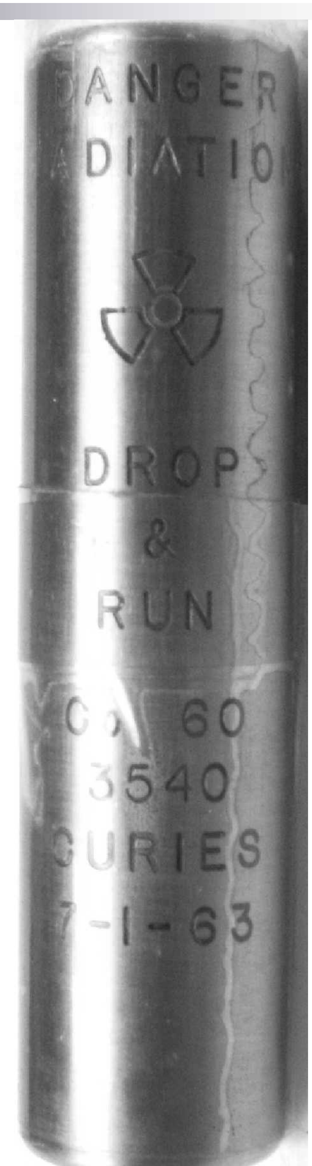
Device Labels





Field Characterization

Source Markings



Characterization

Manufacturers' Documentation

National Nuclear Security Administration
Defense Nuclear Nonproliferation

AEA TECHNOLOGY QSA

Ver. 2004-1112

Americium-241

γ and Primary X-ray Sources

Point Sources

Americium-241 incorporated in a ceramic bead (AMC21 to AMC25) or cylindrical ceramic pellet (AMC26), sealed in a welded stainless steel capsule.

Nominal activity* MBq	mCi	Capsule	Typical photon output in photons/s per steradian 59.5keV	Product code
74	2	X.100	1.0×10^{6} **	AMC21
518	14	X.101/2	7.0×10^{6}	AMC24
1665	45	X.102	$16.2\text{-}21.9 \times 10^{6}$	AMC25
7400	200	X.108	5.5×10^{7}	AMC26

* Tolerance ± 10%
** Tolerance +25%, -10%

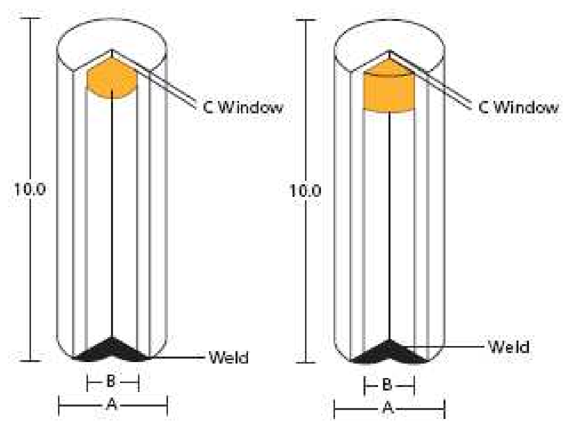
Recommended working life: 15 years

Quality control
Wipe Test I
Immersion Test II
Bubble Test III

59.5keV γ-ray emission is measured in narrow beam geometry using a thin NaI detector.
Spectral purity is checked using Si (Li), Ge and NaI detectors.

Neutron emission
All Americium-241 sources emit 0.3n/s per MBq (~10^4n/s per Ci) due to (α,n) reactions with the low atomic number elements (for example, Si, Al, O) in the active material.

X.100-102 **X.108**

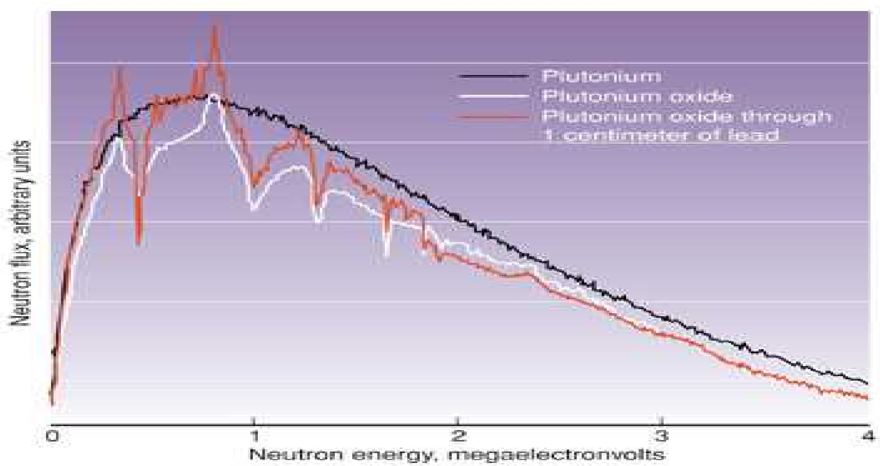


Capsule dimensions and safety performance testing

Capsule	Overall diam. 'A'mm	Active diam. 'B'mm	Window thickness 'C'mm	Safety performance testing ANSI/ISO class	IAEA special form	US-Model number
X.100	2.0	1.0	0.2-0.25	C64444	YES	AMC.Pn
X.101/2	3.0	2.0	0.2-0.25	C64444	YES	AMC.Pn
X.102	4.0	3.0	0.2-0.25	C64444	YES	AMC.Pn
X.108	7.0	5.0	0.2-0.3	C64444	YES	AMC.Pn

Characterization- Identify through Measurement

- Last resort:
  - Dose rate
  - Type of radiation
  - Isotope identifier
  - Quantification?



Source Identification

- IAEA International Catalogue of Sealed Radioactive Sources can help you identify a source:

  Source-Catalogue@iaea.org
- US DOE Off-Site Source Recovery Project, information and contact information at: http://osrp.lanl.gov
- IAEA Nuclear Security Series No. 5, Identification of Radioactive Sources and Devices, Pub 1278,IAEA, Vienna, 2007
- IAEA Web Site: http://www.iaea.org

Management Options for Disused Sources

- Secure in place
- Move to "local/national" store
- Other options available after movement to store could include:
  - Return to source manufacturer
  - Return to country of origin (repatriation)
  - Recycle or reuse

Documentation and Control Containers in Store

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- Detailed inventory of sources/devices by container which includes:
    - Source type, geometry and dimensions – photos if possible
    - Physical and chemical form
    - Activity and manufacture date
    - Contact information for last known user, including S&S team, if appropriate
    - Measured dose rates and contamination levels
    - Unique drum identifier
- Detailed inventory of containers in store
- Permanent marking of drums – exterior and interior tracked to inventory records

Drums in Storage

Summary

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- Safe, secure and compliant packaging and transportation is a key element in the ultimate disposition of sealed sources.
- Field packaging and preparation for temporary storage must not inhibit further processing for return to manufacture, repatriation to country of origin, or long term storage pending development of disposal pathways.
- All information on sources/devices obtained during field operations must be maintained for further use.
- Training and qualification for performance of packaging and transportation is the responsibility of the national authority.
- US origin sources may be registered with the OSR Project at LANL http://osrp.lanl.gov

Information Resources

National Nuclear Security Administration
Defense Nuclear Nonproliferation

- US Offsite Source Recovery Project website: osrp.lanl.gov
- IAEA International Catalogue of Sealed Radioactive Sources
- IAEA Sealed Source Toolkit: http://www.iaea.org/Publications/Booklets/SealedRadioactiveSources/index.html
- Source/device manufacturers, if noted on device or source markings
- US DOE NNSA Global Threat Reduction Initiative, Abby Cuthbertson, abigail.cuthbertson@nnsa.doe.gov
- IAEA -see your IAEA Country Officer