IAEA
International Atomic Energy Agency

4.1 Optimization of occupational radiation protection in industrial radiography Part 1

Industrial Radiography (IR)

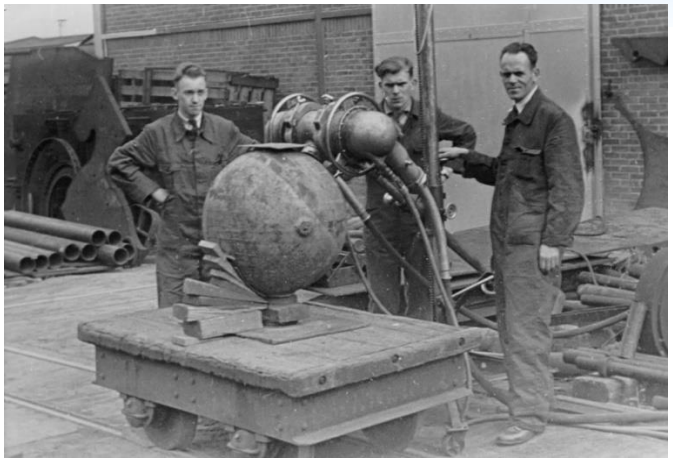
Method of Non-Destructive Testing (NDT) also know as Radiographic Testing (RT)

Radiation sources:

- Radioactive sources
- X-ray tubes
- Linear accelerators

Location:

- Shielded enclosures / Radiation Bunkers
- In the field / customer site
- Onshore / offshore

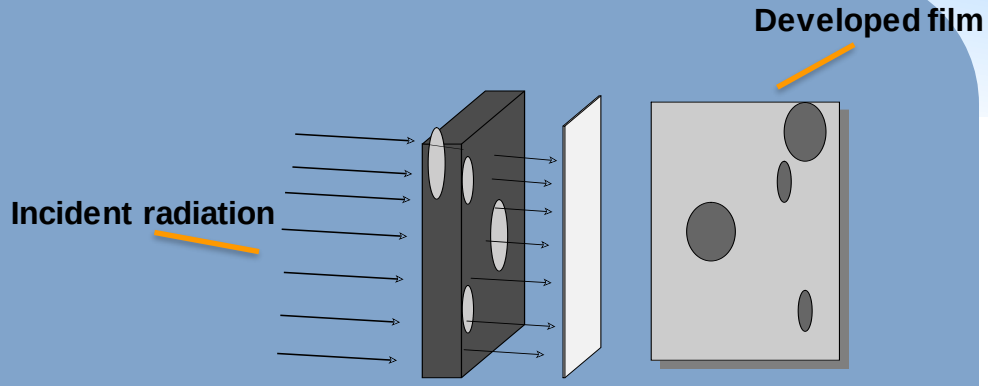


Radiographic testing in the old days
(courtesy Applus RTD, The Netherlands)

Industrial Radiography Principle

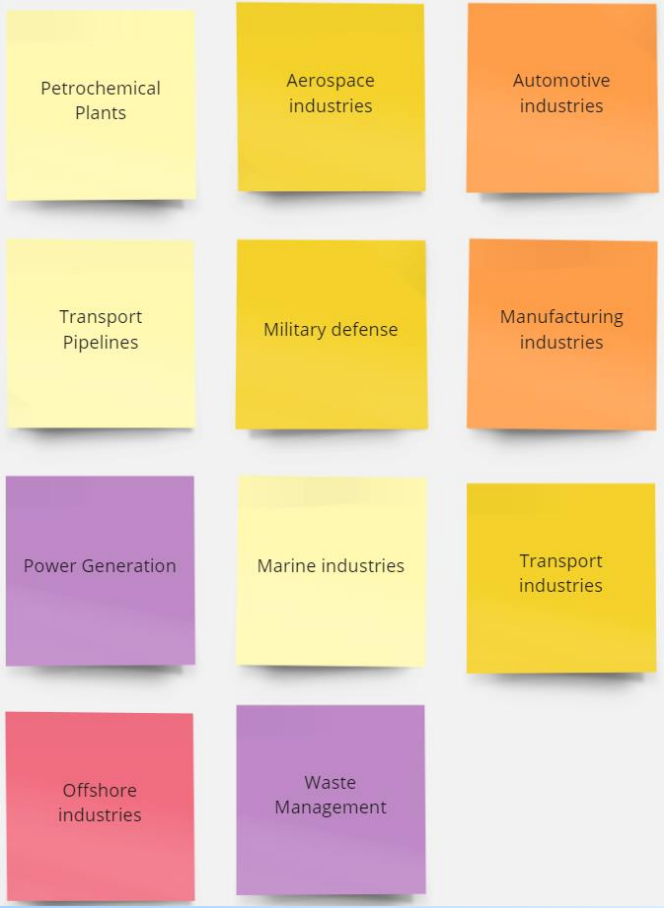
Typical use→ Non Destructive Testing of :

- Welds
- Joints in pipework (pipe crawler equipment) & storage tanks
- Castings (valves, engine components)
- Tyre structure
- Screening of baggage, parcels and food products



Test object is positioned between source of ionizing radiation and film
Potential defects are shown on exposed and developed film

Industries that apply RT / NDT



Industrial radiography is performed in two quite different situations

1. “shielded enclosure”.
2. “site radiography”

Relevant Standards

- ISO 3999

Radiation protection - Apparatus for industrial gamma radiography - Specifications for performance, design and tests

- IAEA-SSR-6 (Rev.1)

Regulations for the Safe Transport of Radioactive Material

- ISO 2919

Radiation protection – Sealed radioactive sources – General requirements and classification

- IAEA SSG-11

SSG-11: Radiation Safety in Industrial Radiography

Gamma radiography sources and exposure containers

- Gamma radiography is carried out with a sealed source that is stored in a safely shielded location within a specially designed exposure container;
- Exposure container is also called exposure device or “camera”.

Different types of exposure containers

- The three **classes** of exposure containers generally operate by exposing the source in one of two ways
- Depending on the way of exposure a distinction is made between two **categories** of exposure containers

Gamma radiography sources and exposure containers

Classification of gamma exposure devices based on their mobillity

P

Portable exposure device
To be carried by one or two persons
(Mass < 2 x 25kg)

M

Mobile exposure device
To be transported with suitable means

F

Fixed, installed exposure device
To be manoeuvred within a certain limited area

Exposure Container **Categories**

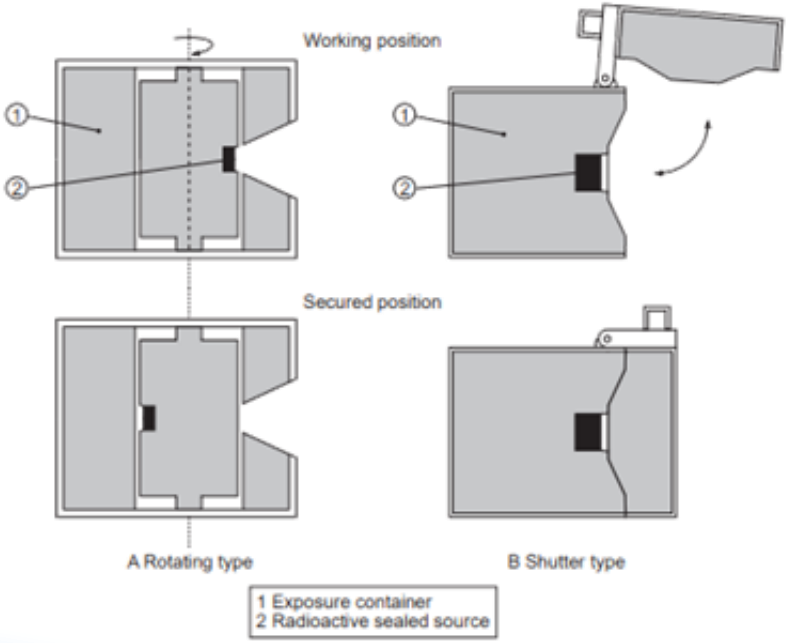
I

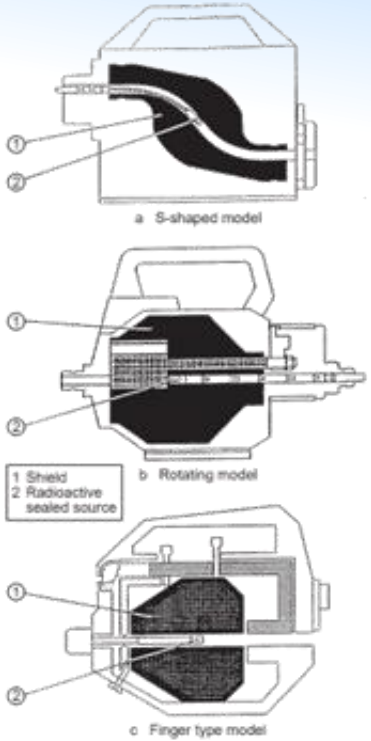
- Shutter type or Rotating type
- Source remains fixed inside the container all times
- Solid angle of beam usually smaller than 60°, further collimation possible
- Exposing by using a handle or remote means

II

- “Projection Container” of “projection type”
- Source is physically projected assemblyout of the shielded exposure container inside a guide tube to the end of this tube

Categorization of gamma exposure devices based on source exposure

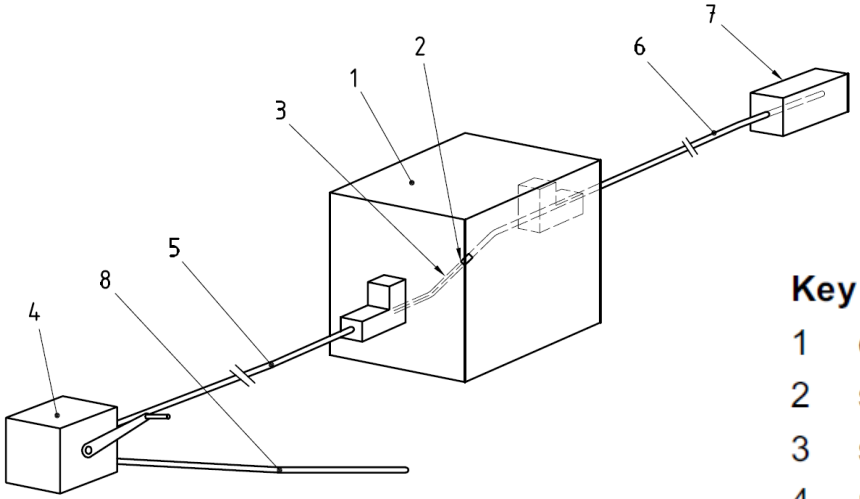




Category I: Source remains in device

Category II: Source is projected outside device

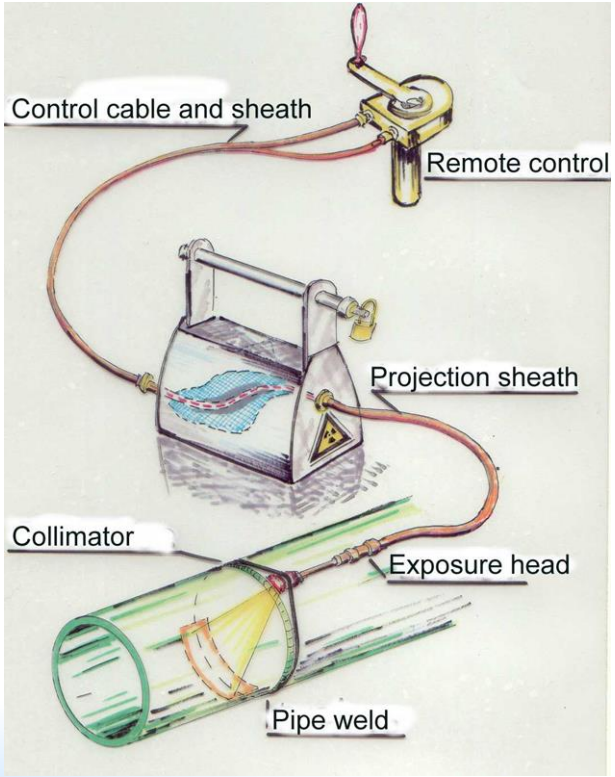
Category II Exposure Device



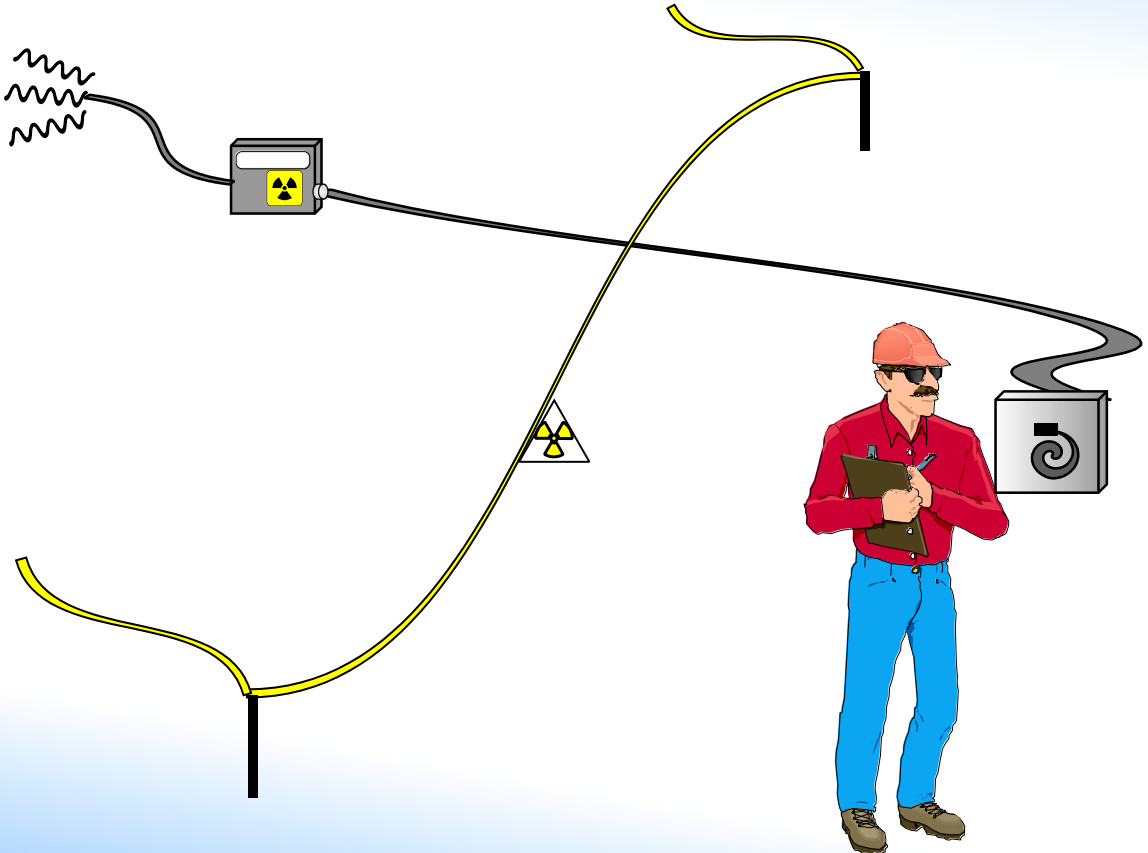
Key

1 exposure container
2 sealed radioactive source
3 source holder
4 remote control
5 control cable and sheath
6 projection sheath
7 exposure head
8 reserve sheath

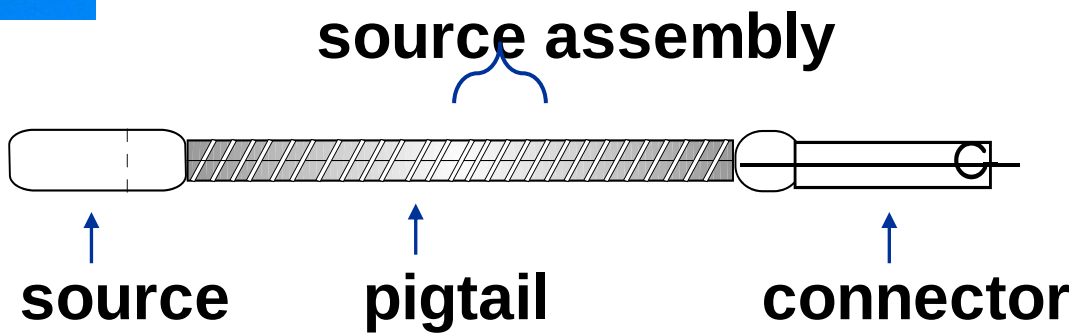
Class P, Category II exposure device



Remote Exposure



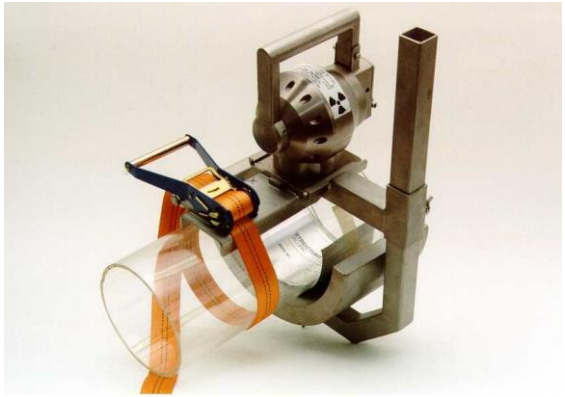
Source assembly

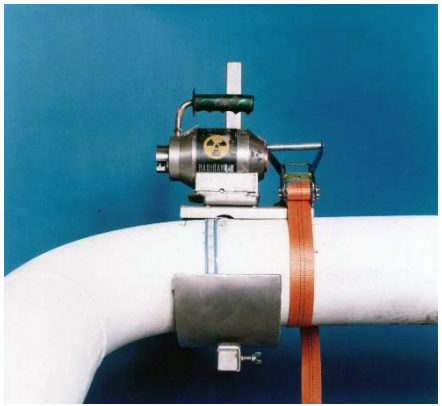


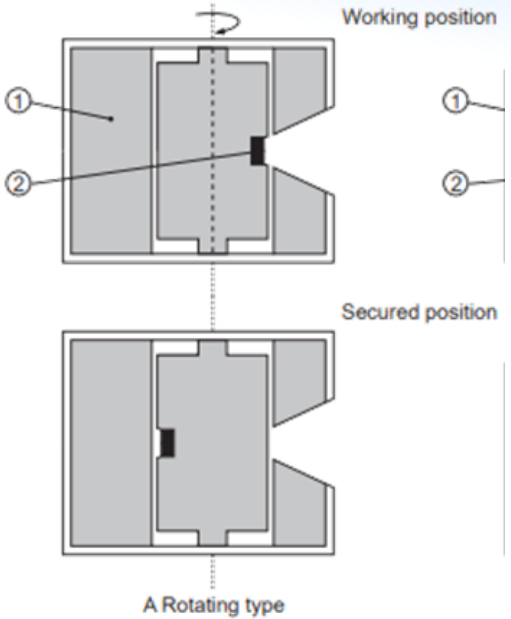
Class M, Category II Exposure Device

(courtesy of Applus RTD, The Netherlands)

Class P, Category I Exposure Device







LORA ("**LO**w **RA**diation") camera
(courtesy of Applus RTD, The Netherlands)

Radioactive sources

Isotope	Gamma energy (MeV)	Half-Value time	Thickness steel equivalent (mm)	Activity (TBq)	Activity (Ci)	Doserate at 1 meter (mSv/h)
Ir-192 (NL)	0.2-1.4	74 d	10-70	5	54	175
Ir-192 (USA)				6	162	525
Se-75	0.12-0.97	120 d	4-28	3	81	127
Co-60	1.17 and 1.33	5.3 y	50-150	4	108	1,051

Maximum dose rates per Class

Class	Maximum dose rate (μSv/h)		
	On external surface	At 50 mm from external surface	At 1 m from external surface
P	2,000	500	20
M	2,000	1,000	50
F	2,000	1,000	100

Use of gamma exposure devices

Not to be used in conditions for which they were not designed;

Effects of corrosion, moisture, mud, sand and other foreign matter are to be considered

Lock

All exposure containers are to be fitted with an integral lock;

The lock retains the key when the source is in the exposed position;

If the lock is damaged it does not prevent the source assembly from returning from the exposed to the secure position

Requirements for Exposure Container

Appropriate for and compatible with the source, the source holder or source assembly;

ISO 3999 standard: designed to ensure that the container can withstand the rigors of Industrial Radiography environments and typical usage

Metallic plate on exposure container

Ionising radiation trefoil symbol

“Danger - Radioactive Materials”

Chemical and mass number of the Radionuclide

(e.g. “Ir-192”, “Co-60”)

Maximum source activity

Conformity with ISO 3999 or equivalent standard

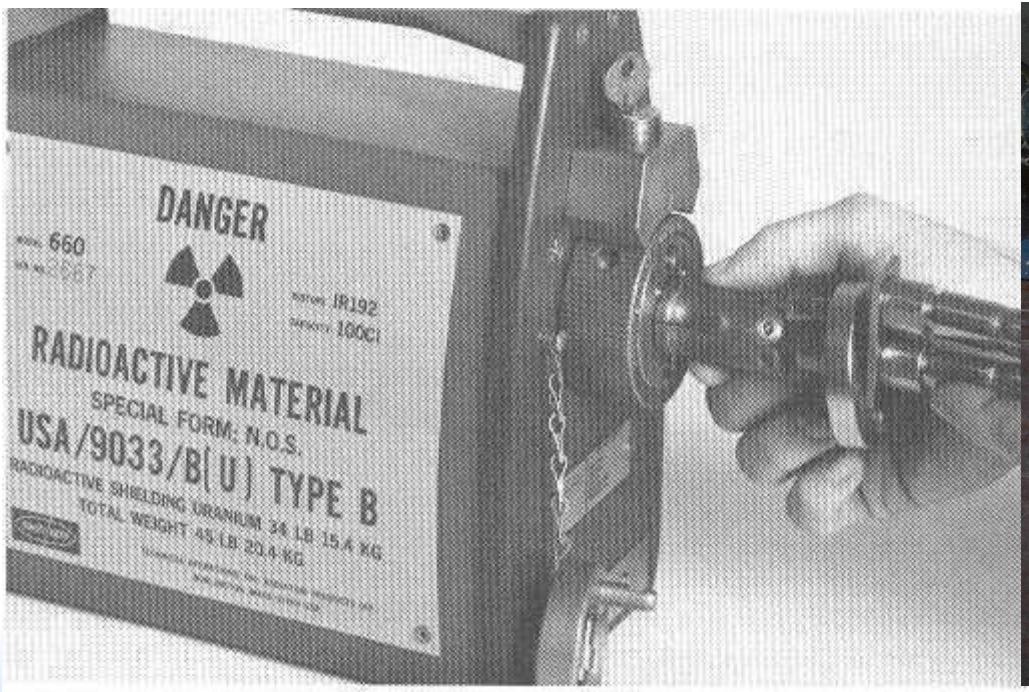
Model and serial number

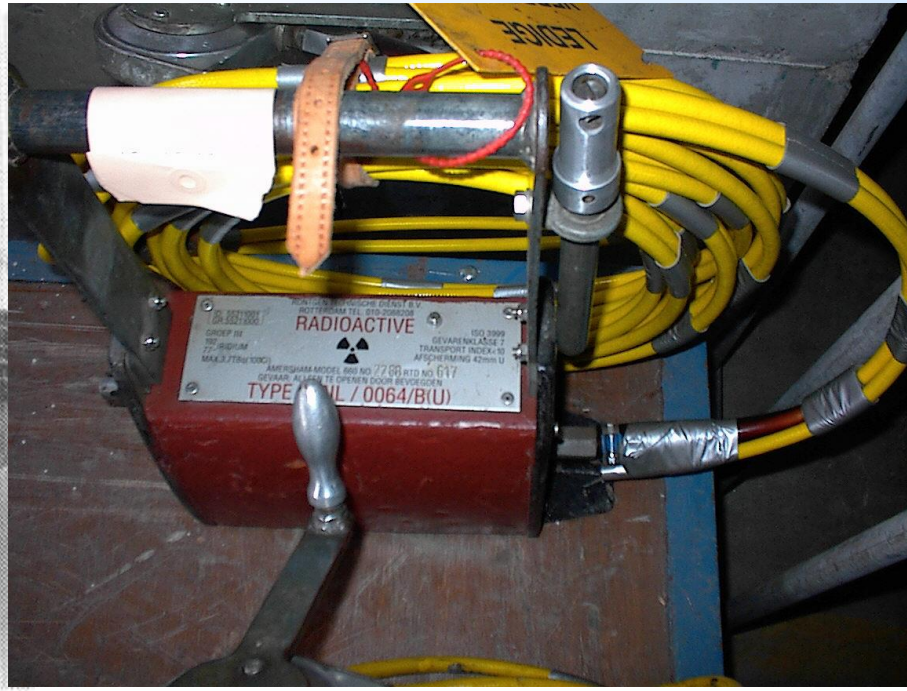
Licensee name and address

Class, category and total mass

Mass of depleted uranium shielding, if applicable, or the indication “Contains depleted uranium”

Metallic plate





Durable fireproof label or tag

- The chemical symbol and mass number of the radionuclide
- The activity and date on which it was measured in Bq (or Ci)
- The identification number of the sealed source
- The identity of the source manufacturer
- To be changed if a new source assembly is installed in the exposure container

Shielding Material

- High specific mass
- High Z material
- Depleted Uranium or Tungsten
- Lead would make exposure container to big

Depleted Uranium Containers

- be treated as radioactive material even if container is empty
- properly stored
- accounted for
- disposed of in authorized manner
- durably marked
- If shielding is unknown: measure radiation level when empty (10 µSv/h at 10 cm)

Requirements for projection type containers

- Proper coupling between source assembly and the control cable
- Automatically secure of source in shielded position
- Protecting covers around connecting fittings or safety plugs
- Guide tubes shall have a closed end
- Drive cables shall have sufficient length
- Radiation levels: < 2 mSv/h at surface and < 0.1 mSv at 1 meter
- Ancillary equipment should be compatible

Typical lengths

Control	Control cables: 7 – 15 m
Guide	Guide tubes: 2 – 6.5 m
Maximise	Maximise distance between radiographer and source

Requirements for Radioactive Sources

- Gamma energy suitable for IR
- Fairly long Half-life (> 1 month)
- ISO 2919:2012 → Radiological protection — Sealed radioactive sources
- Special form Radioactive Material

ISO 2919 Sealed radioactive sources - Classification

- Safety is the prime consideration;
- System of classification based on performance specifications;
- Manufacturer can evaluate the safety of his product;
- User can select suitable sources for his application

Site Radiography – Gamma Radiography
Typical Stages during Normal Exposure