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Environment Agency

RSR Training - Inspection of Closed Radioactive Sources

• **Produced by NTS in Consultation with a sub group of the Non Nuclear Regulation Group.**

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RSR Training - Inspection of Closed Radioactive Sources

Chapter 1 - Introduction to the Course

1. Purpose of the Course

The primary function of this course is to equip you with the necessary additional skills in order to carry out accompanied inspections of simpler closed radioactive sources.

This course will:

- Introduce the basic elements of radioactivity
- Provide guidance on radiation protection and safety
- Give an overview of the equipment that will be used
- Provide an introduction to the Radioactive Substances Act 1993
- Describe typical applications and uses of closed sources
- Explain what will be required to carry out compliance inspections

2. Background

The term **"closed source"** means an object free from patent defect which is radioactive material because it consists of one or more radionuclides firmly incorporated on or in, or sealed within, solid, inert non-radioactive material so as to prevent in normal use the dispersion of any radioactive material. This "definition" does not include sources where there is the potential for contamination of other materials, eg radioactive powders, liquids or gases: these are termed "open sources".

Currently the regulation of closed radioactive sources is carried out by the PIR/RSR section within Environmental Planning teams. The Agency's new Area model shows simpler closed source regulation moving to the Environmental Protection teams.

The main reason for moving the regulation of these sources to the Environmental Protection teams is to ensure that target inspection frequencies can be achieved.

3. Examples of Types of Premises and Applications of Closed Sources

- Electrostatic charge elimination -
  car paint/repair workshops
  paper/plastics/textiles processing

- Level control/density measurement -
  chemical industry
  brewery canning lines
  other product packaging

- Soil moisture/density -
  road-building
  landfill

- Crop flow measurement -
  combine harvesters

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The only closed source regulation that will **not** be transferred to the Environmental Protection teams is large (ie high activity) irradiation sources and radiography sources. This is because of the significant hazards associated with these devices.

The job that you will be expected to carry out involves visiting premises and checking how the user is complying with the terms and conditions of the Certificate of Registration. An inspection proforma will be used, which will also form the basis of a visit report.

(Note that x-ray generators do not contain radioactive materials and, consequently, are not regulated under the Radioactive Substances Act, 1993 (RSA93) - see also Chapter 2, section 13).

Chapter 2 - Introduction to Radioactivity

1. Summary

Radioactive decay is the means by which unstable (high-energy) atomic nuclei are transformed into stable (low-energy) nuclei. Decay is usually accompanied by emission of a sub-atomic particle and the release of energy.

Radioactive emissions can comprise alpha, beta, positron, neutron and gamma radiation. In practice, for nearly all closed sources in common use, consideration can be restricted to alpha-gamma and beta-gamma emission.

Alpha emission results in a "daughter" product of atomic number two units lower and mass number four units lower relative to the parent. Beta emission results in a daughter of atomic number one unit higher and mass number unchanged in relation to the parent. Daughters from both types of decay may themselves be radioactive.

Radioactivity is measured in terms of disintegrations per second, with the unit becquerel (Bq), where one becquerel is defined as one disintegration per second.

2. General

The phenomenon of natural radioactivity is as old as the universe. Certain atoms are unstable and **decay** (according to statistical rules), giving off particles and electromagnetic radiation in the process. Consequently, we all receive regular doses of radiation which come from space (cosmic radiation), from the ground (gamma radiation from naturally -occurring uranium and other elements), and from eating food containing natural radioactivity. Potassium-40 is a naturally - occurring radionuclide present in all potassium, which is an essential component of all living organisms; its presence in human tissue leads to continuous low-level doses of beta-gamma radiation (see below).

During the past hundred years or so, man-made radionuclides have contributed to radiation doses received by human beings. Exposure routes have included deliberate medical procedures (diagnostic and therapeutic), certain large-scale industrial processes (eg nuclear fuel reprocessing) and dispersion of radioactive debris from the atmospheric testing of nuclear weapons. However, as a generalisation, it can be said that doses received as a result of the manufacture, use and disposal of artificial radionuclides have been much lower than those incurred from natural sources.

Following the discovery of radioactivity at the close of the last century, many uses have been found for this property. Radioactive materials have been used in medicine (both therapeutic and diagnostic); in luminising applications; in level, density and flow measurement devices; in tracer studies; in fundamental research; and in many others (see also Chapter 3).

3. Nuclear Particles (nucleons)

The nucleus of a hydrogen atom contains one proton, a massive fundamental particle that carries an electrical charge of +1 (equivalent, but opposite in sign, to the charge carried by one electron). All other atomic nuclei consist of two types of **nucleon** - protons and neutrons. Neutrons are equivalent to protons in most regards, having almost the same mass. Neutrons, however, carry no electrical charge and consequently are not influenced by an electromagnetic field.

4. The Helium Nucleus

A helium nucleus consists of two protons and two neutrons. Two forces are important in a consideration of the stability of such a nucleus: **the electromagnetic force** and the **strong nuclear force**. The electromagnetic force, in the case of any atomic nucleus, is repulsive between the positively charged protons. The nuclear force is always attractive, and is experienced by all nucleons. These forces are balanced in such a way within a helium nucleus that the nucleus is stable. The tendency to electromagnetic repulsion is more than compensated for by the attractive nuclear force. Furthermore, the presence of neutrons tends to "dilute" the electromagnetic repulsion within a nucleus. Without the neutrons, the protons in a helium nucleus would be closer together.

It should be noted that the attractive force experienced by different nucleons (neutron-neutron, proton-proton, and neutron-proton), although having the same approximate magnitude in each case, is not exactly equal in each case. This feature is important when considering the stability of heavier nuclei.

5. Nuclear Stability

For the full range of naturally - occurring nuclei, we can plot the mass number (protons plus neutrons) against the atomic number (protons alone). In such a plot, the stable nuclei are seen to fall within an envelope. Outside this **region of stability**, nuclei can be formed, but are characteristically less stable than those within the envelope.

Three regions of instability can be defined: "neutron rich", "neutron light" (or "proton rich") and "heavy". The "heavy" region is at the extreme reach of the stability envelope. It represents that area of the plot where nuclei become unstable by virtue of their size. In this region, the nucleons at one side of the nucleus can be regarded as being beyond the influence of nucleons at the other side with regard to the very short-range nuclear attractive force, while still being influenced by the (relatively) longer-range repulsive electromagnetic force.

All nuclei outside the stability envelope can be regarded as subject to radioactive decay, to a greater or lesser degree. Each of the three unstable regions is characterised by a different type of radioactive particle decay.
It can be noted here that the ratio of neutrons to protons for stable nuclei (ie within the envelope of stability) increases with atomic number. The ratio for a helium nucleus (see above) is 1:1. For the heaviest naturally occurring element, uranium, the principal isotope has a ratio of neutrons:protons of 146:92, or 1.59:1. This feature is a consequence of the differing magnitudes of the force of nuclear attraction between different types of nucleons (see section 4 above).

6. Particle Decay

Seen in thermodynamic terms, the envelope of stability represents a low-energy region of the mass number vs atomic number plot. Nuclei formed outside the envelope can undergo transformations from the unstable (high-energy) regions to bring themselves within the stable (low-energy) region. There are three such types of transformation, as follows.

6.1 Alpha decay

An **alpha particle** is equivalent to a helium nucleus. When an alpha particle is ejected from a heavy nucleus during the process of radioactive decay, the product ("daughter") nucleus is reduced in atomic number by 2, and in mass number by 4 relative to the parent nucleus. This can be represented by the following scheme, where A is the parent alpha emitter, B the daughter, x the mass number, and y the atomic number:

$$^{x}_{y}A \qquad ^{x-4}_{y-2}B \quad + \quad ^{4}_{2}He$$

6.2 Beta decay

A **beta particle** is equivalent to a high-energy electron. It is emitted from a nucleus in the unstable neutron-rich region of the plot. The mass number remains the same, but the atomic number increases by 1. In this equation, e represents an electron (beta particle), p a proton, and n a neutron:

$$^{x}_{y}A \qquad ^{x}_{y+1}B \quad + \quad ^{0}_{-1}e$$

$$[\,^{1}_{0}n \qquad ^{1}_{1}p \quad + \quad ^{0}_{-1}e\,]$$

6.3 Positron decay and electron capture

A **positron** is equivalent to a positively charged electron. Positron decay occurs from the unstable proton-rich region of the plot. The mass number again remains the same, but in this case, the atomic number reduces by 1:

$$^{x}_{Y}A \qquad ^{1}_{Y-1}B \quad + \quad ^{0}_{1}e$$

$$^{1}_{1}p \qquad ^{1}_{0}n \quad + \quad ^{0}_{1}e$$

For most practical purposes in the context of closed source inspection, the phenomenon of positron decay can be ignored. It is rare, on account of the fact that whereas a number of mechanisms exist for the generation of unstable nuclei in the "neutron-rich" and "heavy" regions, equivalent mechanisms that lead to "proton-rich" nuclei are much less common. In practice, the positron decay mode is only important in the artificial manufacture of special radionuclides which will be encountered only very rarely by inspectors.

Some proton-rich unstable radionuclides do not have sufficient energy available to enable them to decay by positron emission. They decay by a process known as electron capture in which the unstable atomic nucleus "captures" one of the atom's orbital electrons. This capture is usually followed by the emission of surplus energy as gamma radiation. This process is effectively equivalent to positron emission as far as the identity of the daughter product is concerned. Examples you may encounter include iron-55, cobalt-57 and cadmium-109.

7. Neutron Sources

For some applications (eg for density gauging or well-logging), sealed sources that emit neutrons are used. These sources usually contain an alpha-emitting radionuclide (most commonly americium-241) intimately mixed with a non-radioactive "target" element of low atomic number (usually beryllium). The principle of operation is that the alpha particles instigate a nuclear reaction with the target material, which results in the emission of neutrons.

8. Gamma Radiation

Particle emission processes are accompanied by energy release, as the parent nuclei are transformed from high-energy unstable regions to low-energy stability. Some energy is released as kinetic energy of the emitted particles. The remainder appears as high- frequency electromagnetic radiation in the gamma range of the spectrum. There are a few pure gamma emitters, where previous decay by emission of a particle has resulted in a metastable gamma-emitting nucleus, but for almost all of the radioactive materials in everyday use regulated under RSA93, we can categorise the activity as either alpha-gamma or beta-gamma.

9. Statistical Aspects

Radioactive decay is a statistical process. That is, we can only describe the behaviour of an assembly of nuclei. We cannot predict the behaviour of individual nuclei. The phenomenon is described in terms of **activity** (*R*), defined by:

$$R = -dN/dt$$

where N is the number of radioactive nuclei, and t is time. The rate can also be defined in terms of an initial rate (R0):

$$R = R_0 e^{-\lambda t}$$

where λ (lambda) is the nuclide-specific decay constant.

The time required for a sample to decay to half of its original rate is known as the **half-life**, t´, and radionuclides are usually described using this term rather than the decay constant:

$$t^1/_2 = \log_e 2/\lambda = 0.693/\lambda$$

As a general rule of thumb we can say that, for the activity levels found in most closed sources, the passage of 10 half-lives is sufficient for any radionuclide to decay to a point where its activity may be considered negligible.

Quantification of radioactivity reflects these statistics. Radioactivity is quantified in becquerels (Bq), where one becquerel is equivalent to one disintegration per second. One becquerel is therefore a very small unit of activity. In practice, qualifiers (multipliers) are used:

- kilobecquerel (kBq) - 10^3 disintegrations per second
- megabecquerel (MBq) - 10^6 disintegrations per second
- gigabecquerel (GBq) - 10^9 disintegrations per second
- terabecquerel (TBq) - 10^{12} disintegrations per second

The levels most frequently encountered in closed sources are kBq, MBq and GBq. Some TBq-level sources are registered, eg at blood transfusion units or at premises where radiological measurement instruments are calibrated. As mentioned in Chapter 1, it is not intended at present that these higher-activity sources will be regarded as "simpler closed sources" for inspection purposes, and they are to be regarded as outside the scope of this training programme.

10. Decay Series

The heaviest radioactive atoms fall into four **"decay series"**, three of which include between them most of the naturally - occurring radioactive species. The general patterns of all four series are essentially identical. Decay within these series results in daughters which are themselves radioactive. Some of the daughters decay by alpha emission and some via the beta mode. (Note that in no case does a decay series involve a proton-rich positron-emitting daughter.) In some cases (eg actinium-227 and bismuth-211 in the actinium series), the daughters can decay by either the beta mode or the alpha mode. The decay constants, , in each case will be different, and one or other decay mode will dominate. However, it should be noted that each individual daughter nucleus may decay in either of the two modes. That is, the mode by which a given such nucleus will decay is statistical rather than deterministic. The end-point of each of the four series is a stable isotope, eg lead-207 in the case of the actinium series.

11. Nuclear Fission Reactions

Some heavy nuclei resolve the problem of instability dramatically, by spontaneous **fission** into (usually) two approximately equal parts. More commonly, nuclear fission follows neutron capture by a heavy nucleus, eg, for uranium-235:

U235 + n   *U236   Fission Products + (x)n

where * designates an unstable intermediate, and (x) can be in the range 0-9, but, in the case of the above family of reactions, is about 2.5 averaged over all reactions in the family.

The neutrons generated may be available for promotion of further fission reactions; hence the possibility of a **chain reaction** in some well-designed system (eg a bomb or a nuclear reactor).

The reactions are accompanied by a large release of energy; this appears as kinetic energy of the fission fragments, kinetic energy of the released neutrons, and gamma radiation (all of which become degraded into heat).

The neutrons released in such fission reactions are themselves another type of particle radiation, which must be taken into account from the point of view of radiological protection under certain circumstances.

12. Activation and Fission

Most commonly-encountered radionuclides are beta emitters. Beta emitters can arise (or be deliberately produced) as a result of the two processes **activation** and **fission**.

In the process of neutron activation, a stable nucleus absorbs a neutron. The resulting neutron-rich isotope can be unstable, and it resolves the problem of instability by radioactive decay, effectively converting a neutron in the nucleus into a proton with emission of a nuclear electron (beta particle). Activation can take place in a nuclear reactor, where there are a lot of "spare" neutrons as a result of the fission process. That is why so many materials arising from the decommissioning of nuclear reactors - for instance, the components of structural steels - are neutron-rich beta emitters. Some artificially produced radionuclides are generated by deliberate activation; that is,.by neutron bombardment of stable nuclei. Many such processes are carried out commercially to produce radionuclides to order.

The fission process in a nuclear reactor results in "spare" neutrons. Some such neutrons are released during fission, where they can promote further fissions or activate structural materials. Other "spare" neutrons are, in effect, incorporated into the fission products. Fission products are almost always neutron-rich, and are consequently unstable, decaying by the beta emission route to achieve stability.

13. X-rays

As mentioned in Chapter 1, x-ray generators do not contain radioactive materials and are therefore not regulated under the Radioactive Substances Act 1993 (RSA93). It is, however noteworthy that they must be operated in compliance with the Ionising Radiations Regulations 1985 (see Chapters 4 and 6) and inspectors must take appropriate precautions when visiting premises where x-ray generators may be present in addition to radioactive sources.

SOME RADIONUCLIDES LIKELY TO BE ENCOUNTERED

DURING INSPECTIONS OF SIMPLER CLOSED SOURCES

Radionuclide		Half-life	Decay Mode / Radiations Emitted
hydrogen-3 (tritium)	H-3	12.3 y	Beta
iron-55	Fe-55	2.6y	Electron capture
cobalt-57	Co-57	270d	Electron capture
cobalt-60	Co-60	5.3y	Beta, gamma
nickel-63	Ni-63	120y	Beta
krypton-85	Kr-85	10.6y	Beta, gamma
strontium-90	Sr-90	28y	Beta
cadmium-109	Cd-109	1.3y	Electron capture
caesium-137	Cs-137	30y	Beta, gamma
promethium-147	Pm-147	2.6y	Beta, gamma
gadolinium-153	Gd-153	242d	Electron capture
thallium-204	Tl-204	3.9y	Beta
polonium-210	Po-210	138d	Alpha
thorium (natural)		1.4×10^{10}y	Alpha, beta, gamma
uranium (natural) uranium (depleted)		(4.5×10^{9}y)	Alpha, beta, gamma
plutonium-238	Pu-238	86y	Alpha

Chapter 3 - Typical Uses of Closed Radioactive Sources

1. Introduction

Closed radioactive sources are widely used in the process industries, medicine, commerce and research. The uses can be classified as below. All make use of the ionising properties of the radiations the sources emit.

2. Radiography

This technique is used to examine welds, castings, etc, for imperfections. Both x-ray generators (not regulated under RSA93) and closed sources are used. The latter are independent of electrical power supplies and can readily be used in the field. However, they are of sufficient activity to be potentially very hazardous and need strict control in use. You will not be required to inspect them as part of "simple closed source" inspection. (Note that medical radiography uses x-ray generators rather than closed sources.)

3. Analytical Techniques

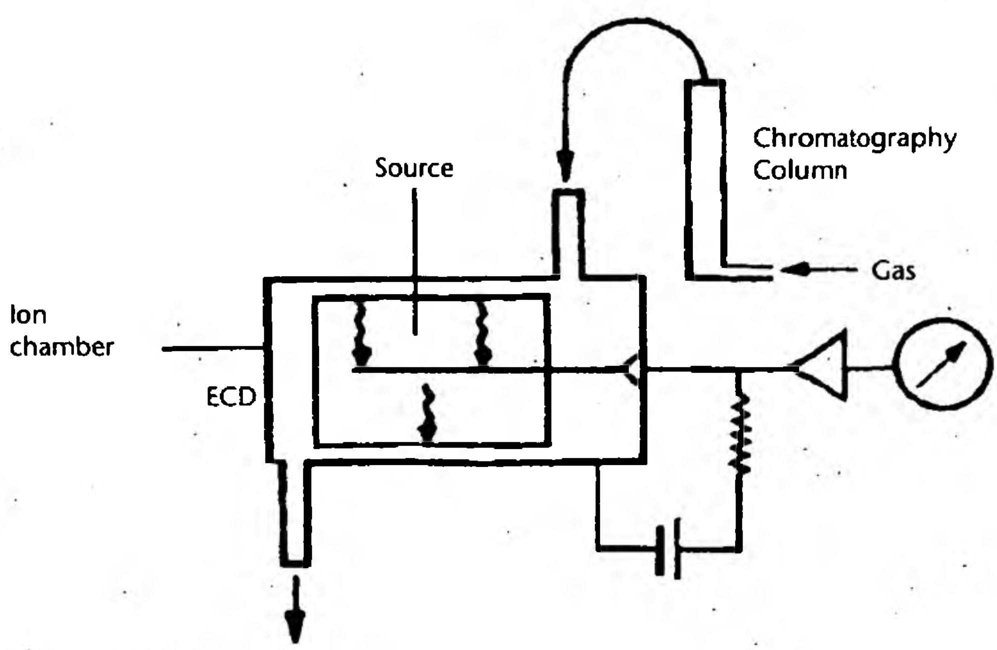
These uses are mainly encountered in laboratories.

3.1 Electron capture detectors

These may be found as part of gas chromatographs and are particularly useful in the detection of halogenated organic molecules. The radionuclide most commonly used is nickel-63 at levels for which there is conditional exemption from some requirements of RSA93. (For details see the Annex to Chapter 6 - Exemption Orders.)

Uses of radionuclides

Electron Capture Detectors - Circuit Diagram



Uses of radionuclides
Electron Capture Detectors

3.2 Neutron activation analysis

This technique may use a closed source of neutrons, usually containing americium-241 at levels requiring registration under RSA93.

3.3 X-ray fluorescence

This method uses a series of closed radioactive sources containing a range of gamma emitters which may include iron-55, cobalt-57, cadmium-109, promethium-147, gadolinium-153, plutonium-238 and americium-241. These are used to excite the characteristic x-radiation of the elements being measured in a sample. It is less widely used nowadays than formerly, but may still be encountered occasionally.

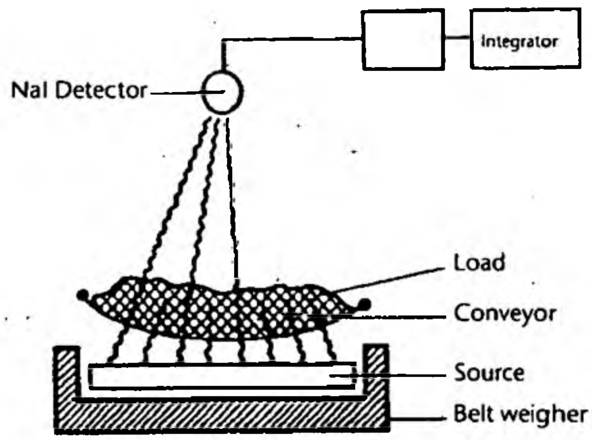
4. Gauging Techniques

4.1 Thickness gauges (transmission).

In this variant of the technique, the source and the detector are on opposite sides of the "sample". The technique is widely used on-line in process industries, typical applications including:

- thickness measurement (plastics, paper, sheet metal, etc)
- bulk flow of material (conveyor or pipe); crop yield meters on combine harvesters are an example
- measurement of contents of packages, eg medicinal tablets, tobacco in cigarettes
  Radionuclides used include krypton-85, strontium-90, caesium-137 and americium-241.

Uses of radionuclides
Belt weighing



4.2 Thickness gauges (backscatter).

Here, the source and detector are on the same side of the "sample". The technique is again used on-line in process industries for the continuous measurement of thin substrates (eg paper, plastics) and also the thickness of coatings, eg on metal.

Radionuclides used include strontium-90, caesium-137, promethium-147, thallium-204 and americium-241.

4.3 Level gauges

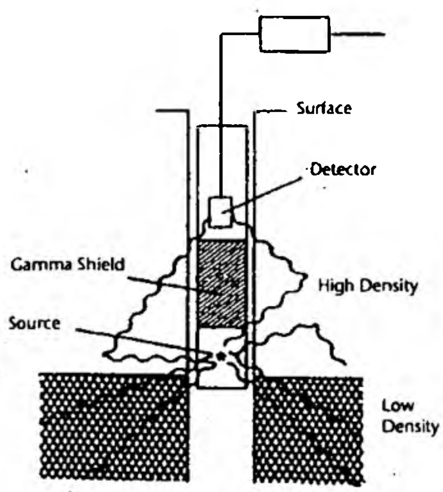
Gamma rays are transmitted from a closed source on one side of a container to the opposite side where a detector indicates whether the contents are at the required level. A more sophisticated variant uses an array of detectors to indicate the level of the contents. Typical uses include packaging monitors (which reject partially filled cans, bottles, etc) and level indicators in process plant such as hoppers and silos.

Radionuclides used include cobalt-60, caesium-137 and americium-241.

4.4 Neutron and gamma scattering

Portable instruments employing this technique are used to measure soil moisture content, bulk density (eg of concrete) and for oil and other well-logging. A commonly-encountered piece of equipment is one used in civil engineering and construction, eg in quality control during road building and concrete laying. It contains both a gamma source (caesium-137) and a neutron source (americium-241 mixed with non-radioactive beryllium).

Uses of radionuclides
Borehole logging



5. Irradiation Processes

These include clinical (therapy) uses and industrial processing (eg sterilisation of surgical supplies, food preservation, induction of chemical reactions). The sources are of very high activity and you will not be required to inspect these as part of "simple closed source" inspection.

6. Miscellaneous Uses

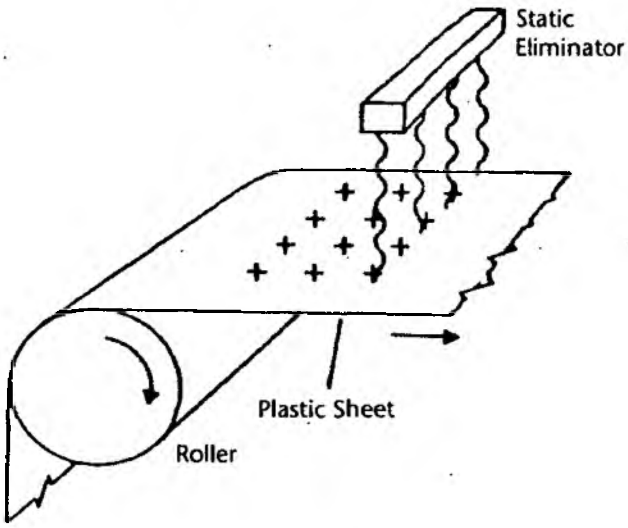
6.1 Static electricity elimination.

Radioactive sources are used to ionise the air in the vicinity of certain industrial processes where static charges can cause operating difficulties. Ionising the air allows the static charges to dissipate safely. Manufacturing industries making use of these sources include textiles, paper and plastics. Another important area of use is in spray painting, eg in motor body and other paint shops.

The radionuclide most commonly used is polonium-210, an alpha emitter, in the form of a foil source.

Uses of radionuclides

Static elimination



6.2 Smoke detectors

These are widely used in the home as well as in industrial and commercial premises. The radionuclide used is americium-241 in the form of a foil source. The principle of operation is that smoke particles interfere with a steady electrical current flowing in a detector in which the air is ionised by alpha particles from the source. An electronic circuit detects the change in the current and activates the alarm. There is an Exemption Order covering these devices (see Annex to Chapter 6) but in some circumstances they must be registered under RSA93.

6.3 Gaseous tritium light devices (GTLDs)

These are small lamps that use radioactive decay as the sole energy source. They consist of small, sealed glass tubes, the walls of which are internally coated with a luminescent material. The tube is filled with gaseous tritium (a radioactive form of hydrogen), the beta radiation from which is converted by the luminescent coating into light. They are used to illuminate certain instruments for field use (especially military) and were widely used some years ago to illuminate emergency exit signs. Other technologies have largely displaced them from the latter market but they may still be encountered in use or awaiting disposal.

Chapter 4 - Radiation Safety

1. Interaction of Radiation with Matter

When radiation passes through matter, including tissue, it deposits some of its energy in the material concerned. It does this principally by transferring energy to atomic electrons, causing them either to be excited to a higher energy level **(excitation)** or to be separated entirely from the atom **(ionisation)**. All energy is eventually lost as heat, but it is the initial ionisation and consequent chemical changes which cause harmful biological effects.

The depth of penetration through matter for a given type of radiation increases with its energy, but it also varies from one type of radiation to another for a given energy. For charged particles such as alpha and beta particles of a given energy, the depth of penetration depends on the size of the particle and its charge. Thus, for equal energies a beta particle will penetrate to a much greater depth than an alpha particle. Alpha particles can scarcely penetrate the dead, outer layer of the skin, so radionuclides that emit them are not hazardous unless they are taken into the body. Beta particles may penetrate a centimetre or so of tissue; radionuclides that emit them are hazardous to superficial tissues, but not to internal organs unless they also are taken into the body. Gamma and x-rays, however, can pass through the body and, therefore, the radionuclides that emit them may be hazardous whether on the outside or the inside of the body.

2. Dose Quantities

The quantity of energy imparted by ionising radiation to a unit mass of matter is known as the **absorbed dose**. It is measured in joules per kilogram and is given the special unit called the **gray (Gy)**.

In tissue, equal absorbed doses from different types of radiation do not necessarily have equal biological effects. One gray of alpha radiation is more harmful than one gray of gamma radiation. The biological effectiveness of a given absorbed dose is dependent on the microscopic distribution of energy deposition. Alpha particles, being heavy and with a double positive charge, readily cause ionisation and give up their energy in short dense straight tracks while gamma radiation is less densely ionising.

(PATTERN OF IONISATION) See Next Page

To take account of this, the absorbed dose is multiplied by the **radiation weighting factor** (previously known as the quality factor). This modified quantity is known as the equivalent dose and is given the special unit called the **sievert (Sv)**. Equivalent dose provides an index of the risk of harm from exposure of a particular tissue to various radiations irrespective of their type or energy: 1 Sv of alpha radiation to the lung, for example, is deemed to create the same risk of inducing fatal lung cancer as 1 Sv of beta radiation to the same organ.

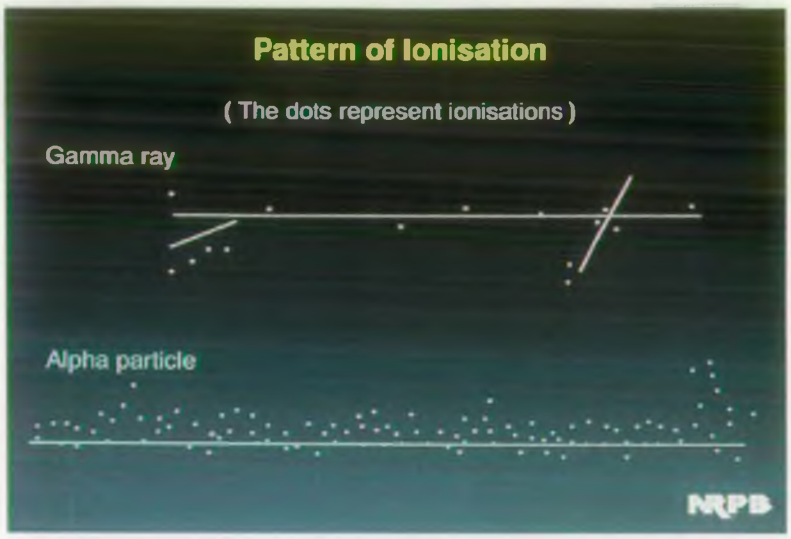
Radiation weighting factors (r)

Type of radiation	r
X-rays, -rays and -particles	1
Protons	5
Thermal neutrons	5
Fast neutrons	5-20*
-particles, fission fragments	20

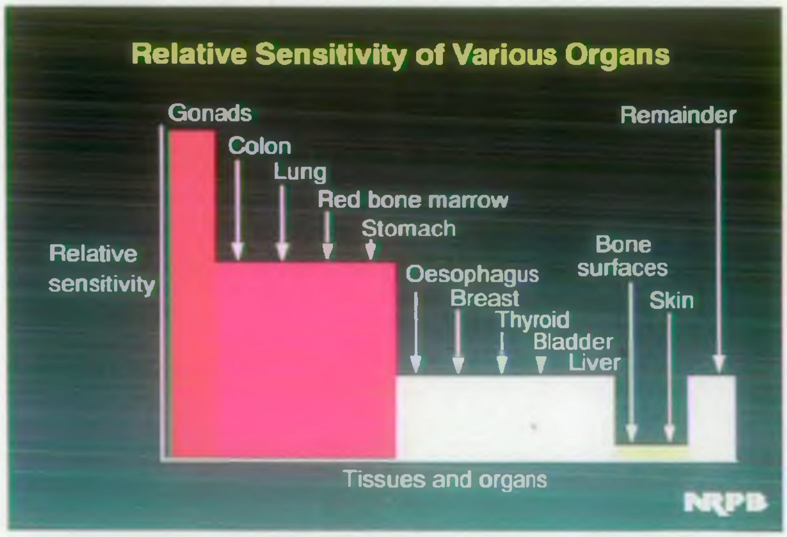
*Depending on energy

Different organs and tissues have differing sensitivities to radiation, eg the risk of fatal malignancy per sievert Sv is lower for the thyroid gland than for the lung.

NRPB Set 8
Pattern of Ionisation



NRPB Set 8
Relative Sensitivity of Organs



To be able to compare doses to different organs, we use the quantity **effective dose**. This is obtained by multiplying the equivalent dose to a particular organ by a tissue weighting factor related to the risk associated with that organ. Where a number of organs are irradiated, the effective dose is the sum of the weighted equivalent doses. Effective dose is thus that dose which, if received by the whole body, would give rise to the same risk as that incurred in the actual exposure. It also has units of sieverts.

Tissue weighting factors

Tissue or organ	*Tissue weighting factor, ω_T*
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05
Whole body	1.0

A further quantity used in radiological protection is **collective effective dose** which is related to the consequences of the exposure of a population or group. Though unlikely to be encountered in the context of "simple closed source" inspection, it is mentioned here for completeness. The unit of collective effective dose is the man-sievert and the quantity is obtained by multiplying the average dose to the population or group by the number of individuals in the group.

3. Biological Effects

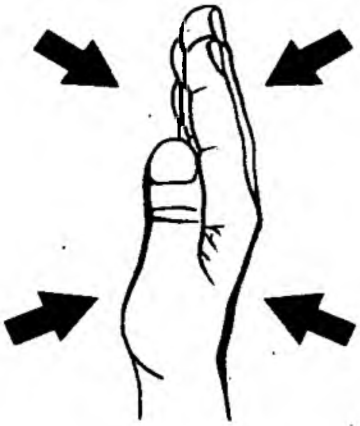
The ways in which radiation damages cells are not fully understood, but many involve changes to DNA. A DNA molecule may be ionised directly by the radiation and undergo subsequent chemical changes, or it may be attacked by free radicals formed following ionisation of the water in the cell. These chemical changes may lead to:

- the early death of the cell or the prevention or delay of cell division; or
- a permanent modification which is passed on to daughter cells.

In the first case, death or prevention of division of cells results in the depletion of the cell population within organs of the body. Below a certain level of dose (a threshold), the proportion of cells damaged will not be sufficient to affect the function of the organ and there will be no observable effect on the organ or the body as a whole. Above the threshold, effects will start to be observed and the severity of the effects will increase quite rapidly as the dose increases. This type of effect is referred to as deterministic. Deterministic effects are usually due to high doses received over a short period of time and occur soon after the exposure (eg acute radiation syndrome, skin erythema). One deterministic effect that may not occur for many years is damage to the lens of the eye.

Deterministic Effects

Few 100s mSV	-	Temporary and minor changes in blood cells
2.5 to 5 Sv	-	Substantial damage to blood cells Blood forming tissue Gut



2 Sv or more	-	Reddening of skin
Higher Doses Still	-	Loss of hair Dermatitis Ulceration

In the second case, modification of even a single cell may result, after a latency period, in a cancer in the exposed individual or, if the modification is to a reproductive cell, the damage may be transmitted to later generations and give rise to hereditary effects. In these cases, it is the probability of the effect occurring that depends on the dose. This type of effect is referred to as **stochastic**, meaning "of a random or statistical nature". These are the effects with which we are mainly concerned at the low dose levels usually encountered in occupational exposure, and it is the risk of these effects that provides the basis for the tissue weighting factors used to calculate effective dose. The overall risk of fatal cancer from an effective dose of 1 Sv is about 5%.

The aim of radiation protection is to **prevent** deterministic effects and to **limit the probability** of stochastic effects to levels deemed to be acceptable.

4. Practical Protection Measures

When dealing with closed sources, radiation protection is principally concerned with the **external radiation hazard**, ie that arising from sources of radiation outside the body. Alpha radiation is not generally regarded as an external hazard as it cannot penetrate the outer layers of the skin, but beta, gamma, neutron and x-radiation can all penetrate to the sensitive organs of the body. We can control the external hazard by applying the three principles: time, distance and shielding.

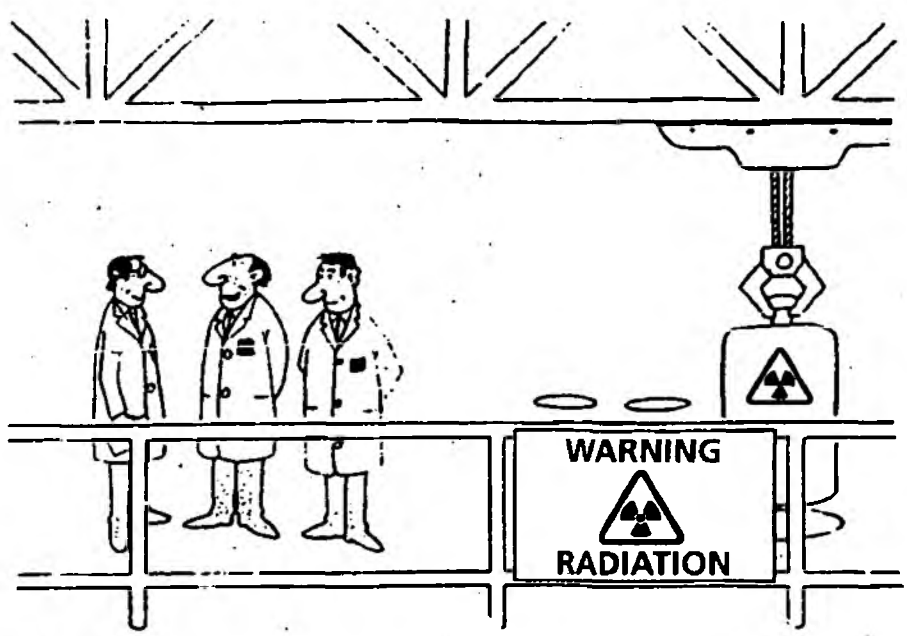
Time

The dose accumulated by a person in an area having a particular dose rate is directly proportional to the amount of time he or she spends in that area:

$$\text{dose} = \text{dose rate} \times \text{time}$$

The dose can thus be minimised by limiting the time spent in the area.

Minimise Exposure Time



On the job discussions in a radiation field should be avoided

Distance

The intensity of radiation from a source decreases with the distance from the source. For a point source, the dose rate at a distance r from the source is Inversely proportional to the square of the distance r (the inverse square law):

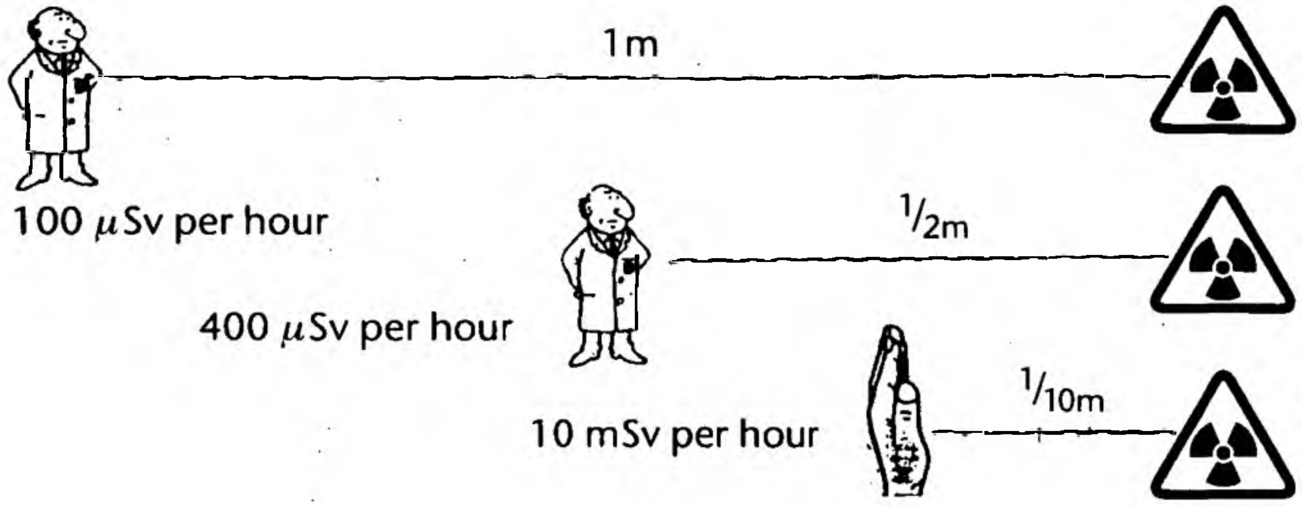
$D = k/r^2$ where k is a constant for a particular source and

$D_1 r_1^2 = D_2 r_2^2$ where D1 is the dose rate at distance r_1 from the source and
D_2 is the dose rate at distance r_2 from the source)

Doubling the distance from the source thus reduces the dose rate to one-quarter of its original value; trebling the distance reduces the dose rate to one-ninth; and so on. It follows that the dose rate increases very rapidly on close approach to a source. For this reason:

Sources should never be handled directly with the fingers.

Doserate Vs Distance



Shielding

The external radiation hazard can be reduced or eliminated by the use of appropriate shielding materials.

For **beta** radiation, in the energy range normally encountered, about 10 mm of Perspex will provide complete absorption. A problem that can occur when shielding against beta radiation is the emission of secondary x-rays, which result from the rapid slowing down of the beta particles. Production of this x-radiation, known as bremsstrahlung, is proportional to the atomic number of the absorber. Beta shields should thus be constructed of materials of low atomic number such as aluminium or Perspex.

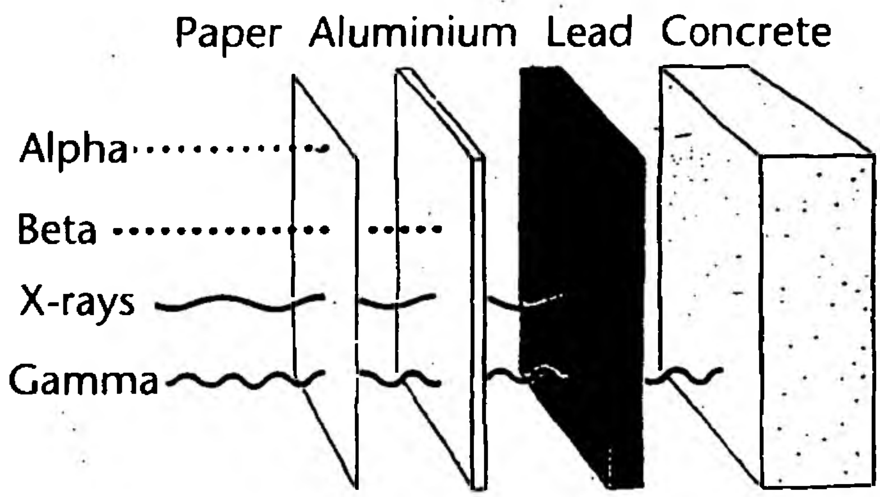
Gamma and **x-radiations** are attenuated exponentially when they pass through any material. The linear absorption coefficient Ê is a function of the type of material used for the shield and of the energy of the incident radiation. In general, dense materials of high atomic number (eg lead) are the best absorbers. The thickness of shielding which will halve the x-ray or gamma-ray dose rate is called the **half value layer** (HVL). Standard tables of HVLs are available which enable shielding calculations to be carried out quickly and easily.

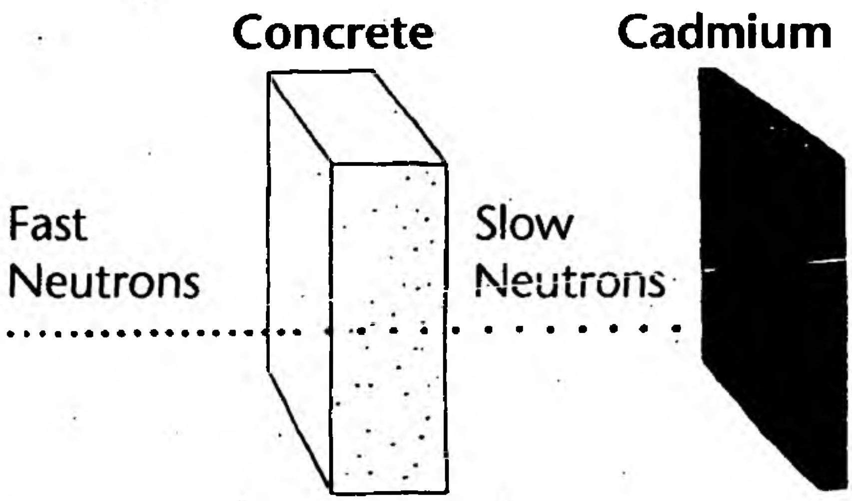
Half value layers - gamma absorption

y - radiation energy (MeV)	Half Value Layer	
	mm of lead	mm of water
0.5	41	50
1.0	11	190
1.5	15	210
2.0	19	225

Shielding Materials

Types of Radiation





Damaged sources

Under normal conditions, closed sources should present only an external hazard ie external to the body. However, if a closed source is damaged, radioactive material may escape and can then cause an **internal radiation hazard**. Such material may enter the body by inhalation, by ingestion or through the skin (particularly if the skin is broken). Quite small quantities of radioactive material, which represent an insignificant external hazard, can give rise to appreciable dose rates if they get inside the body or contaminate the skin. If you come across a situation where you suspect that a source may have been damaged it is thus imperative that you get expert help and do not try to deal with the situation yourself. **Do not put yourself at risk**. Step back and contact your Radiation Protection Supervisor (RPS) or an experienced Radioactive Substances inspector for support and advice.

5. Legislation Related to Radiological Protection

In most countries worldwide, the starting point for regulation of ionising radiation is the recommendations of the International Commission on Radiological Protection (ICRP). This is a non-governmental scientific organisation which has published recommendations on protection against ionising radiations for over half a century. Within the EC, ICRP recommendations are incorporated into a "Basic Safety Standards Directive" issued under the provisions of the Treaty establishing the European Atomic Energy Community (EURATOM).

The requirements of the directive are, in turn, incorporated into UK national legislation by means of the Ionising Radiations Regulations (IRRs) made under the Health and Safety at Work, etc Act 1974.

The current regulations were issued in 1985 to implement the BSS Directive adopted in 1980. The latter was based on ICRP's 1977 recommendations. These were revised in 1991 and a new BSS Directive was adopted in May 1996. The latter is required to be incorporated into national legislation by 2000. Revised IRRs are currently in preparation .

Ionising Radiations Regulations 1985

The basic principle in the Regulations (IRR 85) is that all necessary steps should be taken to reduce so far as is reasonably practicable the extent to which people are exposed to ionising radiation, ie it is not sufficient merely to observe the dose limits specified in the regulations.

Dose limits are specified for various categories of persons and refer to the sum of all radiation doses (internal and external) arising from work activities. Any person who is likely to receive a dose exceeding three-tenths of a relevant dose limit must be designated as a "classified person" and be subject to medical surveillance.

Annual dose limits

	Whole Body (effective dose)	Individual Organ (equivalent dose)	Lens of the Eye
Employee aged 18 or over	50 mSv (20 mSv)	500 mSv	150 mSv
Trainee aged under 18	15 mSv (6 mSv)	150 mSv	45 mSv
Any other person	5 mSv (1 mSv)	50 mSv	15 mSv
Figures in brackets are limits likely to be specified in revised IRRs			

Special dose limits for women

Abdomen of woman of reproductive capacity (employee)	13 mSv in any 3 consecutive months
Abdomen of pregnant woman (employee)	10 mSv during declared term of pregnancy (1 mSv to foetus in revised regs?)

To facilitate the control of doses, the Regulations require "controlled" and "supervised" areas to be identified where there is a likelihood of people receiving doses in excess of three-tenths and one-tenth, respectively, of the annual dose limit for workers aged 18 years or over. Any person entering a controlled area must be designated as a classified person, unless he or she enters under a written system of work designed to ensure that a significant dose cannot be received. There must be regular assessment of doses received by classified persons using approved dosimetry services. Where a non-classified person enters a controlled area in accordance with a written system of work, a personal dose assessment or other suitable measurements must be made, to demonstrate that doses are appropriately restricted.

The general requirement to keep doses as low as reasonably practicable is supported by a number of requirements relating to control of the source of radiation, including the following:

- Provision of safety devices, warning signals, etc
- Regular leakage testing of radioactive sources
- Provision of protective equipment and clothing
- Regular monitoring of radiation and contamination levels

- Safe storage of radioactive substances

- Contingency arrangements for dealing with possible incidents

The employer must ensure that adequate training and information on potential hazards are provided to persons working with ionising radiation. Such work should be supervised to the extent necessary to ensure that the requirements of the Regulations are met and this normally necessitates the appointment of a Radiation Protection Supervisor (RPS). Radiation Protection Advisers (RPAs) should also be appointed where expert advice is needed or when an employer has to designate one or more controlled areas.

Application to closed source inspections

1. Officers should apply the principles of time, distance and shielding to ensure that their accrued dose is as low as reasonably practicable. In particular, officers should never handle sources directly.

2. Agency officers are most unlikely to accrue doses above three-tenths of the dose limit, so will not be designated as classified persons.

3. There may occasionally be a need to enter controlled or supervised areas. Requirements of any local rules or written system of work issued by the site management should be followed.

4. Electronic personal dosemeters (of a type recommended by the RPS) will be made available and should be worn on all RSR inspections. Dose on a single visit should not normally exceed 10 ÊSv and will, in the main, be much less than this. In the event of a high dose reading or a dose-rate alarm, retreat and ask the operator to check the dose-rate. It should be noted that electronic dosemeters are susceptible to radiofrequency interference (eg from mobile phones) which can give false high readings.

5. If in doubt about any radiation safety issue, consult your RPS or another experienced RSR inspector.

6. Officers should not attempt to carry out inspections for which they have not been trained eg radiography sources, irradiation sources, open sources.

7. Officers should not attempt to deal alone with situations for which they have not been trained eg damaged closed sources - seek help from your RPS or an experienced RSR inspector.

8. Follow Staff Health & Safety Instruction No.27.

6. Radiation Doses in Perspective

Officers taking sensible precautions and carrying out about 30 closed source inspections per year are unlikely to accrue an effective dose in excess of 20 µSv per year. This is about the same as that from a single chest x-ray, and is less than 1% of the average dose to a UK resident from natural background radiation.

The risk of fatal cancer from a dose of 20 µSv per year is about the same as that from smoking one cigarette per year!

COMPARATIVE SCALE OF DOSES, LIMITS AND EFFECTS

mSv	
10000—	
	2000 Threshold for early death
1000—	
	500 Threshold for nausea
100—	
	50 Worker dose limit (current)
	20 Radon action level (homes); worker dose limit (future)
10—	
	8 Cornwall - average annual dose from all sources
	2.5 UK - average annual dose from natural radiation
1—	
	0.3 Highest individual annual dose from Sellafield discharges
0.1—	
	0.02 Closed source inspection (one year); single chest x-ray
0.01—	0.01 Average flight to Spain
0.001—	

Chapter 5 - Portable Radiological Instruments Used in The Environment Agency

1. Personal Radiation Dosemeters

The comments in section 5 of Chapter 4 also apply here.

1.1.1 **Standard instrument**

- Gothic Crellon Ltd "Bleeper Sv"

  This is the meter recommended by the national RPS Group. Details are available from your regional RPS.

1.1.2 Other instruments

- Appleford
- Merlin Gerin
- RA Stephen 6000

  These are available and used in some Agency regions. Some have operating facilities that will not normally be required for "simple closed source" inspections.

(Note that film or TLD badge dosemeters are not recommended for simple closed source inspections and should not be used in place of the electronic meters mentioned above.)

2. Other Instrument Types

Some other instrument types are used by PIR/RSR specialist inspectors for use on higher risk inspections. They will not normally be required for simple closed source inspections - they are mentioned here as follows for completeness.

2.1 Gamma Doserate Meters

2.1.1 **Standard instrument**

- Mini Instruments Type G (compensated Geiger tube based)

2.1.2 Other instruments

- Mini Instruments "Smart Ion" (ion chamber based)
- Mini Instruments "MiniRad 1000" (compensated Geiger)

2.2. Contamination Survey Monitors

2.2.1 **Standard instrument**

- Ratemeter (NE Technology RM5, RM6 or Electra; Mini Instruments Type 1500) plus probes:
  Type AP2 - alpha monitor
  Type BP4 - beta monitor
  Mini Instruments Type 44B - low-energy gamma/x-rays

(Note that the Type 44B probe is also used in conjunction with the Mini Instruments 900 ratemeter as a free-standing instrument.)

2.2.2 Other Contamination Survey Monitors

- Mini Instruments "MiniCon 1000" beta/gamma monitor
- NE Technology PCM5 ratemeter with dual phosphor probe - simultaneous alpha and beta monitor.

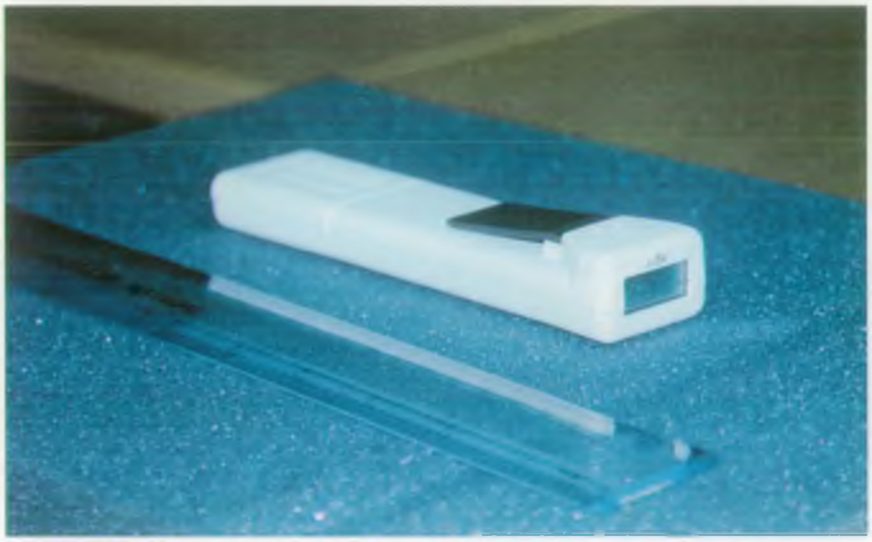
3. "Specials" (held by some Regions only).

3.1.1 Gamma spectrometers

- Lab Impex "Gamma Scout"
- "Exploranium" Type C-130

3.1.2 Large crystal gamma monitor (sodium iodide crystal detector and NE Technology ratemeter)

Personal Dosemonitor - "Bleeper Sv"



"Standard Kit" Contamination Monitor

Chapter 6 - Radioactive Substances Legislation

1. Introduction

In the United Kingdom, there are a number of legislative instruments which deal with the effects of, and protection from, ionising radiation. The three principal instruments are:

1. The Radioactive Substances Act 1993 as amended by the Environment Act 1995 (EA95). This is abbreviated to RSA93 in these notes.

2. The Health and Safety at Work, etc Act 1974 (in particular, the Ionising Radiations Regulations of 1985).

3. The Nuclear Installations Acts 1965 and 1969.

The Ionising Radiations Regulations are concerned with the protection of employees who come into contact with radiation in the course of their work. The Nuclear Installations Act details the requirements on the operators of licensed nuclear sites (for instance, nuclear fuel reprocessing plants or nuclear power stations). RSA93 concerns the keeping and use of radioactive materials, and the accumulation and disposal of radioactive waste. It is noteworthy that RSA93 applies to "undertakings" such as companies, partnerships, hospitals and universities: it does not apply to individual citizens in the privacy of their own homes.

As a generalisation, we can say that the Ionising Radiations Regulations are concerned with possible health effects within a premises (ie to employees), and RSA93 is concerned with the health effects (actual or potential) to the general public. However, care needs to be taken with this distinction, and there is some overlap and possible conflict between the requirements of these two pieces of legislation. A Memorandum of Understanding exists between the Agency and the Health and Safety Executive (HSE) which effectively lays down how any such possible conflicts are to be resolved. Furthermore, Environment Agency inspectors are themselves subject to the requirements of the Ionising Radiations Regulations, since they may be exposed to ionising radiation in the course of their work.

The Environment Agency and its inspectors have regulatory responsibilities only under RSA93, but this does not mean that the other two pieces of legislation can be ignored. The Agency has to work with the HSE to ensure that its decisions are not in conflict with those of other agencies, and that the proper balance is struck between, say, the protection of a workforce and the protection of the public. The Agency's PIR/RSR teams liaise directly with HSE as required.

2. Principles Underlying All Legislation on the Regulation of Radioactive Substances

All three pieces of legislation listed above are based on three fundamental principles of radiological protection. These are:

2.1 Justification

It is recognised that any use of radioactive material will lead to a radiation dose to workers, to members of the public, or to both. The International Commission on Radiological Protection has decided (conservatively) that the dose-risk relationship is linear, with no lower threshold. This means that every dose received by a human being is regarded as increasing the risk, for that person, of sustaining harm - for instance, a cancer. For this reason, each use of radioactive material requires a justification. Do the benefits of using this material outweigh the increase in risks? If not, then the use is not justified.

Examples of justified practices are given in Chapter 3. For example, flow measurement devices represent a justified use of radioactive material, whereas the incorporation of such material in toys or jewellery would not. Justification issues are dealt with at the time of determining an application under RSA93. For that reason, routine inspections will not normally deal with justification.

2.2 Optimisation

Are the doses received by human beings as low as possible with regard to the particular operation or practice being carried out? For instance, does an operation use two radioactive sources where one would do? This idea is encompassed in the ALARA principle, which states that doses should be "As Low As Reasonably Achievable, economic and social factors being taken into account".

When an inspector visits premises for a routine inspection, optimisation is the main principle on which he or she is required to make a judgement. For example, if sources are not locked away in adequately shielded containment when not in use, then the operation at the premises cannot be said to be optimised, since people may be receiving doses of radiation unnecessarily.

2.3 Limitation

Notwithstanding ALARA, and whether the doses have been optimised as far as possible, there are certain upper limits that must not be exceeded.

This issue is not particularly important during routine inspections. Occasions when an operation could lead to doses even approaching an appropriate limit are extremely rare. In most cases, the actual dose received as a consequence of operations involving simple closed sources is likely to be at least an order of magnitude below any limit.

3. RSA93 Certificates.

There are two types of certificate issued by the regulator under RSA93: **Registration** certificates are issued for the keeping and use of radioactive sources; **Authorisation** certificates are issued for the accumulation and disposal of radioactive wastes. For closed sources, we need only consider Registrations. Registration certificates are also used for **mobile** closed sources to permit such sources to be used across a number of premises (eg industrial radiography sources). The distinction between mobile and non-mobile sources is not always clear-cut, but a number of precedents have been set over the years. This distinction may not be of great importance in the inspection of simple closed sources, but it can be important to an operator since the charging regime is more onerous for mobile sources.

4. Registration - Conditions

The mechanism for regulation of holders of closed source is via the conditions imposed on the Registration certificate. There are a number of standard conditions which apply in most cases and which are discussed in Chapter 7. However, some Registrations will contain modified or additional conditions. These modified or additional conditions will have been incorporated into the Registration by the site inspector, either at the time when the application was determined, or as a result of a subsequent inspection (or problem) at the premises.

Note that some conditions are hard and fast; for instance those relating to labelling of a source container. Other conditions are fairly open; for instance, the inspector must use some judgement during an inspection to determine whether, in his or her opinion, "the user has, so far as is reasonably practicable, prevented the loss of any registered source". Such judgements will depend on the specific environment (physical, financial, managerial) at the premises in question.

5. Exemption Orders

Some sources are exempted from the requirement for Registration - see the Annex to this chapter for a list of current Exemption Orders (EOs). This does not mean, however, that exempted holders are exempt from the other requirements of RSA93. They may still be required, for instance, to keep proper records of receipts and disposals, to notify the authorities if sources are lost or damaged, and so on. They can also be inspected (if we can find them). It is often the case that both registered and exempt sources will be found at the same premises. It is quite in order for the person carrying out an inspection to check that the terms of the relevant EO are being adhered to.

The most frequently encountered EOs in this context are those dealing with gaseous tritium light devices (GTLDs), waste closed sources and testing instruments. It is recommended that new inspectors study these three in particular.

6. MoD Sites

MoD sites are Crown Property, and as such, exempt from the requirements of RSA93. However, there are voluntary arrangements by which the MoD enters into a form of pseudo-regulation. There are differences in administration and charging, and in the type of enforcement action that can be taken, but as far as routine inspections are concerned, closed sources at MoD sites are dealt with in exactly the same way as they would be at any other site.

7. Powers of Inspectors

Inspectors have the power to enter registered premises at any reasonable time, and any other premises where they have reason to believe that sources are being used illegally. They may enter premises at the invitation of the occupier/owner; with a Magistrate's warrant; or in emergency situations (defined as situations where members of the public are endangered).

Inspectors should study the relevant sections of RSA93 (as amended by EA95) for more details of their powers before commencing any inspection work. They should also be familiar with those powers as detailed on their warrants.

8. Charging

RSA93 provides for cost recovery from regulated parties and the Agency operates a charging scheme under these powers. Although the details of the scheme covering small closed sources are fairly straightforward, many questions (and complaints) are raised by the holders of Registrations. (The obvious rule with such questions, and indeed any others, is that when you are unsure of the answers, write down the question(s), promise a timely answer and seek advice back at the office.) Those carrying out inspections should therefore be familiar with the details of the charging scheme as a prerequisite. In particular, the differences in charging for mobile and non-mobile closed sources require study.

9. Summary

Environment Agency inspectors are responsible for delivering regulation under RSA93 but must be aware of the relationship between RSA93 and related legislation. Chapter 7 gives detailed guidance on inspection.

RSA93 regulation works through a system of Registration conditions and regular inspections by competent inspectors. Compliance with some conditions can be checked against a yes/no checklist. Compliance with other conditions requires a measure of judgement. A major element in an inspection is to check that the principle of optimisation is being applied.

New inspectors need to be familiar with RSA93, especially those sections relating to powers; Exemption Orders; the charging scheme; and the standard Registration conditions.

ANNEX TO CHAPTER 6

EXEMPTION ORDERS UNDER RSA93

This Annex is based on Inspector's Technical Note ITN/RAS No. 6 which was issued on 28 March 1996 by an Agency predecessor body (HMIP).

1. Introduction

1.1 This note provides an introduction to the basis for Exemption Orders (EOs) made under the Radioactive Substances Act, and summarises some of their key features. With the exception of an amendment to the earlier Hospitals Exemption Order, all current orders were made under RSA60, but they continue in force under RSA93 as though their provisions applied to the corresponding sections in the 1993 Act.

1.2 This note should be regarded only as an aide-memoire: **it is not a substitute for reading and understanding the detailed provisions of each EO (and for seeking advice from more experienced colleagues as necessary).**

2. Legislative Basis

2.1 The powers to make Exemption Orders in England are held by the Secretary of State for the Environment. The same powers in Wales and Scotland are held by the Welsh and Scottish Secretaries of State, in accordance with their role as Environment Secretaries for their respective territories. The Secretaries of State may thus grant exemptions from the need for the keeping and use of radioactive materials and mobile radioactive apparatus to be registered under Sections 7 and 10 of RSA93, and from the need for the accumulation and disposal of radioactive waste to be authorised under Sections 14 and 13 of RSA93.

2.2 In practice, when it is decided to make an EO, that legislation usually applies to the whole of Great Britain. A single Statutory Instrument is issued for England and Wales, signed by both Secretaries of State. But a separate Statutory Instrument may be made for Scotland, with a different SI number.

2.3 The Radioactive Substances (RAS) Division of DETR's Directorate of Pollution Control and Wastes is responsible for formulating EOs on behalf of the Secretary of State. The Environment Agency advises RAS Division on the regulatory and technical (including radiological) aspects of EOs.

2.4 It is for a user to confirm whether an EO is relevant to his use of radioactive material or disposal of radioactive waste. In general, the provisions of an EO apply **in addition to** any limits specified in a certificate of Registration or Authorisation issued to a user: an exception is the Hospitals EO (SI 1990 No. 2512).

2.5 Inspectors' powers of entry which may be relevant to the inspection of exempted holdings or disposals are specified in RSA93 Section 31, subsections (4), (5), (6) and (7) (as amended by EA95).

3. Purpose of Exemption Orders

3.1 For a single or relatively few like cases of a practice involving the use and/or disposal of radioactive substances, individual certification (registration and/or authorisation) is appropriate. But some practices or products involving radioactive substances are very widespread; these include cases in which the radioactivity is an essential property, eg smoke detectors, and cases in which radioactivity is an unavoidable concomitant, eg phosphate fertilisers. If the Agency were required to issue individual certificates to each user in these cases, this would not only be a massive administrative burden on the Agency, but it would also be liable to discourage the conduct or use of a useful practice or product.

3.2 Generally, EOs have been introduced in the following circumstances:

- where a widespread use or disposal of radioactive substances exists or is envisaged;

- where either the use of radioactivity is justified, or its presence is unavoidable; and

- where the radiological hazards can be shown to be negligible, or can be made so by observance of conditions in an Order.

3.3 Each EO has been prepared after detailed consideration of the practice or practices which it was intended to cover, although Orders have frequently been framed in general terms so that very similar practices or products containing radioactivity would also be exempted. Thus, in drawing up an EO, specific attention has been given as to whether the practice was justified, and where necessary, conditions as to quantities or mode of use or disposal have been placed, so as to limit the radiological impact.

3.4 In summary, EOs are set to define the lowest limit of control on radioactive substances; overall, they are governed by three main principles:

- in order to reduce the administrative burden, the mechanism of regulation through Registration/Authorisation should not be applied for its own sake;

- by exempting trifling uses of radioactive substances, more effort can be directed towards more important cases; and

- limitations and conditions can, and where necessary have been, imposed by the Order so as to provide "codes of safe practice".

4. Radiological Criteria for Exemption; Review of EOs

4.1 Criteria have been set internationally by the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA), and nationally for the UK by the National Radiological Protection Board (NRPB). There are some differences in detail between the recommendations of the different bodies. But essentially the principles are that, for an individual practice to be exempted from regulatory control, it should produce:

- an individual dose no greater than 10 microsieverts per year; and

- a collective dose no greater than 1 man-sievert per year.

4.2 Some EOs have been in force since the early 1960s. In view of developments in the standards of radiological protection, a research contractor (Associated Nuclear Services Ltd) was engaged in 1987 to review the EOs that were then current. The contractor's report "A Review of the Justification for Exemption Orders, and for other Low-Level Radioactive Waste Disposal Practices" (reference DOE/RW/87.069, in two volumes plus corrigendum):

- established a method by which the radiological impact of waste disposals under EOs could be assessed;

- used that method to provide an assessment for each EO; and

- included an interesting appendix explaining the historical basis for each EO.

4.3 In general, the Associated Nuclear Services report provided reassurance that the EOs conformed with modern radiological criteria. Its assessment method was subsequently used to develop the conditions in a revised EO for small uses of radioactive substances in hospitals (SI 1990 No 2512) which was brought into force at the time when all NHS hospitals lost their Crown immunity from registration under RSA60 (as one of the amendments made to RSA60 by EPA90).

4.4 The UK's system of Exemption Orders is under review by DETR's RAS Division, to examine the changes that may be required by the revision of the EC Basic Safety Standards Directive. A revised Directive was adopted in 1996 and it must take effect by the end of 1999.

5. Exemption Orders Currently in Force

5.1 The current EOs (including Amendment Orders made to the Smoke Detectors EO and the Substances of Low Activity EO) are listed in Table 1.

5.2 Summaries of limits on materials and wastes, as exempted by various EOs, is given in Tables 2 and 3. Additionally, the Orders for Waste Closed Sources, Schools Etc, Smoke Detectors, Gaseous Tritium Light Devices, Luminous Articles and Testing Instruments exempt the disposal of certain waste closed sources referred to in those Orders by despatch/removal to a person appropriately authorised under Section 13(3) of RSA93, or to a manufacturer of the same kind of source. **An EO must be examined carefully**, since many contain limitations and conditions on exemption which are of very specific application.

5.3 Inspectors should note that HMSO has allowed most of the EOs dating from the 1960s to become out of print - even though they remain current legislation. It may therefore be advisable to send a user a photocopy of any of relevant EOs.

5.4 The definitions of radioactive material and radioactive waste in Sections 1 and 2 of RSA93 should be read in conjunction with the provisions of the Substances of Low Activity EO and the associated Amendment EO (SIs 1986 No 1002 and 1992 No 647). These provide lower limits for artificial radioactive elements, below which any associated material or waste is exempt from the provisions of Sections 7, 13(1) and 13(3) of RSA93. Thus, in the case of a solid substance (other than a closed source), which is substantially insoluble in water:

- In determining the activity of that substance for the purpose of deciding whether it is radioactive material or radioactive waste , the activity of any of the natural radioactive elements specified in Schedule 1 of the EO is disregarded, up to the values specified in that Schedule. This effectively qualifies the definition of "radioactive waste" in section 2(b) of RSA93.

- When the activities of the natural radioactive elements have been disregarded to that extent, then if the activity concentration in the substance does not exceed 0.4 Bq/g, the substance is both exempt from the need for Registration under Section 1, and is excluded from the need for Authorisation under sections 13(1) and 13(3) of RSA93. This provision, in Articles 2 and 3(a) of the EO, effectively puts a lower limit on the activity concentration of natural and man-made radionuclides: this bears on Sections 1(2)(b) and 2 of RSA93.

5.5 It is suggested that Inspectors who are responsible for regulation under RSA93 should generally familiarise themselves with the current EOs by reading them, but recognise that the best way to learn about their applicability is by referring to actual cases.

TABLE 1 CURRENT EXEMPTION ORDER

Title *	Examples	Statutory Instrument
Exhibitions	Small sealed sources used for demonstrating the properties of radiation	1962 No. 2645
Storage in Transit	Storage of radioactive materials at an airport warehouse or waste en route to an incinerator	1962 No. 2646
Phosphatic Substances, Rare Earths Etc	Applies to naturally occuring radioactive material, eg certain ores, certain alloys, lighter flints	1962 No. 2648
Lead	Exempts natural levels of radioactivity in lead from registration	1962 No. 2649
Uranium and Thorium	Thoriated metals, ceramics, gas mantles and special light bulbs	1962 No. 2710
Prepared Uranium and Thorium Compounds	Allows the keeping and use of small amounts of U and Th as chemical reagents (maximum of 2 kg total)	1962 No. 2711
Geological Specimens	Rocks and minerals that contain natural radioactivity, eg uranium ores	1962 No. 2712
Waste Closed Sources	This allows an operator to dispose of sealed sources (which were held under a registration) without authorisation	1963 No. 1831
Schools Etc	Allows schools to hold small closed sources for experiments and demonstrations	1963 No. 1832
Precipitated Phosphate	This is rarely encountered and applies to purification of phosphoric acid by alkali	1963 No. 1836
Electronic Valves	Small amounts of radioactivity are incorporated into valves which are used in radar, navigational and surge arrester equipment	1967 No. 1797
Smoke Detectors		1980 No. 953

Smoke Detectors (Amendment)	DIY stores	1991 No. 477
Gaseous Tritium Light Devices (GTLDs)	Self-luminous emergency exit signs	1985 No. 1047
Luminous Articles	Applies to luminous dials for watches and instruments.	1985 No. 1048
Testing Instruments	Gas chromatography detectors and x-ray fluorescence analysers	1985 No. 1049
Substances of Low Activity		1986 No. 1002
Substances of Low Activity (Amendment)		1992 No. 647
Hospitals		1990 No. 2512
Hospitals (Amendment)		1995 No. 2395

* Abbreviated titles. Full titles are in the following format, using the first on the list as an example: The Radioactive Substances (Exhibitions) Exemption Order 1962. SI 1962 No. 2645.

TABLE 2 ACTIVITY LIMITS FOR KEEPING AND USE OF RADIOACTIVE MATERIALS SPECIFIED BY EXEMPTION ORDERS MADE UNDER RSA60

Exemption Order	Activity Limits
Exhibitions; SI 1962 No. 2645	Homogeneous source: › 370 MBq, no alpha emitters Sealed source: › 37 MBq Open source - not more than the following, for each radionuclide: ^{3}H 370 MBq; ^{14}C 370 MBq; ^{24}Na 37 MBq; ^{32}P 3.7 MBq; ^{35}S 37 MBq; ^{59}Fe 3.7 MBq; ^{60}Co 3.7 MBq; ^{90}Sr 37 kBq; ^{131}I 370 kBq; ^{137}Cs 3.7 MBq; ^{198}Au 3.7 MBq; ^{226}Ra 3.7 kBq
Storage in Transit; SI 1962 No. 2646	Limits per package: (^{227}Ac + ^{241}Am + ^{243}Am + ^{249}Cf + ^{250}Cf + ^{252}Cf + ^{243}Cm + ^{244}Cm + ^{245}Cm + ^{246}Cm + ^{237}Np + ^{238}Pu + ^{239}Pu + ^{240}Pu + ^{242}Pu + ^{231}Pa + ^{226}Ra + ^{228}Th + ^{230}Th) › 37 kBq (^{228}Ac + ^{249}Bk + ^{144}Ce + ^{242}Cm + ^{154}Eu + ^{210}Pb + ^{241}Pu + ^{210}Po + ^{230}Pa + ^{223}Ra + ^{224}Ra + ^{228}Ra + ^{222}Rn + ^{90}Sr + ^{227}Th + ^{230}U + ^{232}U + ^{233}U + ^{234}U + ^{236}U) › 3.7 MBq All other radionuclides, in total: › 37 MBq
Phosphatic Substances,Rare Earths Etc; SI 1962 No. 2648	(a) Specified rare earth elements (or compounds of them or alloys incorporating them): concentration of each of the RSA93 Schedule 1 elements to be › 37 Bq/g (b) Other materials: concentration of each of the RSA93 Schedule 1 elements to be › 15 Bq/g
Uranium and Thorium; SI 1962 No. 2710	(a) No numerical limit on quantities of materials having the following descriptions: a solid or liquid substance containing › 4% natural Th; hardener alloy for Mg-alloy production; incandescent mantle; article of thoria ware (b) Other material: › 2 kg of (U+Th) on the premises
Prepared Uranium and Thorium Compounds; SI 1962 No. 2711	› 2 kg of (U+Th) on the premises
Geological Specimens; SI 1962 No. 2712	(Natural minerals containing U and/or Th). › 100 kg of (U+Th) on the premises

TABLE 2 (contd.)

Exemption Order	Activity Limits
Schools Etc; SI 1963 No 1832	(a) Closed sources: total holding › 148 MBq (b) Open sources: total holding › 74 MBq; total activity brought on to the premises › 74 MBq in any four week period
Electronic Valves; SI 1967 No 1797	Refers to "Class 1" and "Class 2" valves - see Table 3 for definitions Class 1 valves, and Class 2 valves incorporated in equipment, are exempted unconditionally. Total holding of "loose" Class 2 valves: › 10 such valves.
Smoke Detectors; SI 1980 No. 953 amended by SI 1991 No. 477	(a) Exemption for smoke detectors kept "loose" (not affixed or attached to the premises): › 40 kBq of ^{241}Am (only) in each detector; › 500 such detectors in total b) Exemption for smoke detectors affixed or attached to premises: › 4 MBq of all radionuclides in each detector; no limit on number of detectors held
Gaseous Tritium Light Devices; SI 1985 No. 1047	(a) "Class A" (each GTLD containing › 20 GBq): total holding › 5 TBq (b) "Class B" (each GTLD containing › 1 TBq, with › 80 GBq in any one sealed part): total holding › 30 TBq
Luminous Articles; SI 1985 No. 1048	Each article: either › 80 MBq of ^{147}Pm or › 4 GBq of ^{3}H Total activity on premises: › 40 GBq of ^{147}Pm; › 200 GBq of ^{3}H
Testing Instruments; SI 1985 No. 1049	Activity per source, or per instrument containing one or more sources: Homogeneous source 0.4 MBq Laminated or sealed source 4 MBq Electrodeposited source containing ^{55}Fe 200 MBq Electrodeposited source containing ^{63}Ni 600 MBq Tritium foil source 20 GBq
Hospitals; SI 1990 No. 2512 amended by SI 1995 No. 2395	Applies to open sources containing no alpha-emitters. Total holdings as follows: ^{99}Tc › 1 GBq; all other radionuclides (in total) › 100 MBq, of which › 20 MBq comprises radionuclides which are radioisotopes of iodine

TABLE 3 ACTIVITY LIMITS FOR WASTE DISPOSAL SPECIFIED BY EXEMPTION ORDERS MADE UNDER RSA60

Exemption Order	Solid Waste"	Liquid/Gaseous Wastes
Phosphatic Substances, Rare Earths Etc; SI 1962 No. 2648	(a) Substantially insoluble waste consisting mainly of one or more of the specified rare-earth elements (or compounds of them): concentration of each of the RSA93 Schedule 1 elements to be › 37 Bq/g (b) Other substantially insoluble waste: concentration of each of the RSA93 Schedule 1 elements to be › 15 Bq/g	Liquid: Waste to contain particles of the solid waste (only)
Uranium and Thorium; SI 1962 No. 2710	(a) Mg alloy/thoriated tungsten/dross from hardener alloy: no numerical limit (b) Other material: › 100g of (U+Th), "substantially insoluble in water", per day	
Prepared Uranium and Thorium Compounds; SI 1962 No. 2711	› 100g of (U+Th) per day, for solid + liquid wastes together	Liquid: › 100g of (U+Th) per day, for liquid + solid wastes together. Liquid waste disposed of by a means used to dispose of non-radioactive waste Gaseous: › 1g of (U+Th) per day
Geological Specimens; SI 1962 No. 2712	Natural minerals containing U and/or Th: (a) If "substantially insoluble in water", › 100g of (U+Th) per day (b) Other waste: 2g of (U+Th) per month, in solid + liquid wastes together	Liquid: › 2g of (U+Th) per month, in liquid + solid wastes together
Schools Etc SI 1963 No. 1832	No alpha emitters or ^{90}Sr › 370 kBq in 0.1 m^3 of refuse › 37 kBq in any one article › 370 kBq per week	No alpha emitters or ^{90}Sr Liquid: 18.5 MBq per week, to foul water/trade effluent drain system Gaseous: › 37 kBq per day

TABLE 3 (contd) ACTIVITY LIMITS FOR WASTE DISPOSAL SPECIFIED BY EXEMPTION ORDERS

Electronic Valves SI 1967 No 1797	**(Solid Waste only)** a) Class 1 Valves, defined as each having: $\left[KBq\frac{(^{60}Co)}{3.7} + KBq\frac{(^{63}Ni)}{3.7} + KBq\frac{(^{137}Cs)}{3.7} + KBq\frac{(Th)}{3.7} + KBq\frac{(^{204}Tl)}{3.7} + KBq\frac{(^{226}Ra)}{3.7} \right.$ $\left. + KBq\frac{KBq(U)}{3.7} + KBq\frac{KBq(^{14}(C)}{3.7} + KBq\frac{KBq(^{36}C1)}{3.7} + KBq\frac{KBq(^{147}Pm)}{185} + KBq\frac{KBq(^{85}Kr)}{370} + KBq\frac{KBq(^{3}H)}{5550} \right] \not> 1.0$ - These are exempted unconditionally. b) Class 2 Valves defined as each having: $\left[KBq\frac{(^{60}Co)}{3.7} + KBq\frac{(^{63}Ni)}{3.7} + KBq\frac{(^{137}Cs)}{3.7} + KBq\frac{(Th)}{3.7} + KBq\frac{(^{204}Tl)}{3.7} + KBq\frac{(^{226}Ra)}{3.7} + KBq\frac{KBq(U)}{3.7} + KBq\frac{KBq(^{14}(C)}{370} \right.$ $\left[+ \frac{KBq(^{14}C)}{370} + KBq\frac{KBq(^{31}C1)}{370} + KBq\frac{KBq(^{147}Pm)}{1110} + KBq\frac{KBq(^{85}Kr)}{3700} \right] \not> 1.0$ Not more than 10 such valves to be disposed of, per week.

TABLE 3 (contd.) ACTIVITY LIMITS FOR WASTE DISPOSAL SPECIFIED BY EXEMPTION ORDERS

Exemption Order	Solid Waste*	Liquid/Gaseous Wastes
Smoke Detectors; SI 1980 No 953 amended by SI 1991 No 477	For waste arising from detectors containing 40 kBq of ^{241}Am. Limit is 40 kBq of ^{241}Am in 0.1 m^3 of waste + refuse.	-
Gaseous Tritium Light Devices; SI 1985 No 1047	20 GBq of ^{3}H in any GTLD (ie "Class A" GTLDs only); 1 GTLD in any 0.1 m^3 of non-radioactive waste.	-
Luminous Articles; SI 1985 No 1048	Individual articles contain either 80 MBq of ^{147}Pm or 4 GBq of ^{3}H; 10 such articles to be disposed of per week.	-
Testing Instruments; SI 1985 No 1049	'Closed' sources; 200 KBq of all radionuclides per source; 1 such source disposed of per week.	-
Hospitals SI 1990 No 2512 amended by SI 1995 No 2395	No alpha-emitters. a) 400 kBq in 0.1 m3 of the waste. 40 kBq in any one article. b) By burning: 25 MBq of (^{3}H+^{14}C) per month; 5MBq of all other radionuclides per month. Covers solid and flammable liquid wastes, and includes transfers to another hospital or to an authorised premises for disposal by burning there.	Aqueous Liquid: No alpha-emitters. Disposal to drainage system which drains to a public sewer. For human excreta, 1.0 GBq of ^{99}m Tc, 500 MBq of all other radionuclides, per month. For wastes other than excreta, 50 MBq of all radionuclides per month.

* Unless burning is specified, the disposal route required is generally removal by a waste collection authority or its contractors, or disposal to a tip, dump or pit, used solely for the deposit of substantial quantities of refuse which is not radioactive waste. However, the EOs for Luminous Articles, Testing Instruments and Smoke Detectors do not allow the latter option.

Chapter 7 - Inspection

1. Introduction

This chapter sets out the most important things to look out for during an inspection visit. Visits can be pre arranged or unannounced. In general, inspections tend to be pre-arranged unless there are suspicions, eg from previous experience, that an operator is failing to comply with his Registration. If in doubt, consult a PIR/RSR inspector.

The Annex to this chapter is a checklist which can be used both in planning an inspection and as an aide-memoire during an inspection visit.

2. Site Visit; Personal Safety

Always take your personal dosemeter when carrying out RSR inspections. On arrival at the site, switch on the dosemeter and check that it reads zero. (It is sometimes the practice that dosemeters are left on continuously. In such cases, record in your inspector's notebook the reading at the start of the visit, ie on entering the premises.)

In the case of a pre-arranged visit, check in with reception and ask to see the site contact with whom the visit has been arranged.

At all times it is vital to remember that your personal dosemeter will warn you only of increased gamma radiation levels. It will not detect alpha or, in general, beta radiation. Therefore, when inspecting sources that emit beta radiation, do not attempt to get too close to the source. (In plant that is correctly installed and operated, it should not normally be possible to be exposed to hazardous levels of beta radiation, but don't rely on this.)

At the end of a visit, record the reading of your personal dosemeter in your inspector's notebook.

3. Inspection

Purpose: to check that the registered user is compliant with the terms and conditions of the certificate of registration.

The target inspection frequency is between once every two years and once every five years for these sources.

The inspection basically falls into three sections:

- Pre-visit preparations
- Site visit
- Report and follow-up actions

3.1 Pre-visit preparations

Obtain the relevant case files from the Technical Support Officer in the PIR/RSR team. Check the file for any previous visit report(s) and ascertain whether there are any outstanding actions or recommendations.

Read any recent correspondence and make brief notes if necessary; note the site contact, address, numbers, types and strengths (activities) of the sources on the inspection proforma.

Telephone the site contact and arrange a date and time for the visit; this may be particularly necessary where the sources are located in hazardous environments, eg level detectors on cupola furnaces where there may be dangerous levels of carbon monoxide during melts.

3.2 Site visit

On arrival at the site switch on your personal dosemeter and check that its reading is zero. (If the dosemeter is left switched on permanently, record its reading in your inspector's notebook.)

Ask to see the site contact and ensure that he/she escorts you to the source location. Ask the site contact to show you where the source is housed and the location of the metal identification plate. (It may not be possible to get close enough to read the details and therefore inspection of the records will be necessary to complete this section of the inspection.)

Check each section of the report proforma (see Annex to this chapter).

3.3 Report/follow-up actions

The report proforma should be completed as far as is possible. Any additional information, especially with respect to non-compliance issues, should be attached to the report.

This report must be placed with the case file and returned to the PIR/RSR team technical support.

If there are no compliance issues, then a standard letter can be sent to the user. However, any non - compliance issues will be dealt with by the site PIR/RSR inspector in accordance with standard procedures.

3.4 Some issues that may need to be addressed

3.4.1 User no longer occupying the premises. The aim will be to ascertain whether the sources were safely and lawfully disposed of by the registered user. The current occupant may be able to provide information on the whereabouts of the registered user or whether anything was left on the premises which might contain a radioactive source. If further enquiries are needed, the case should be referred to the PIR/RSR team.

3.4.2 User no longer keeping sources. Obtain copies of records of disposal of sources. If records are no longer available, ask user to provide, by a specified date, documentary evidence of disposal. Check whether the operator wishes the registration to be cancelled.
Note that the current standard certificate contains a requirement for the user to inform the Agency prior to cessation of use; this may not be included in earlier certificates.)

3.4.3 Damaged sources. If sources are/may be damaged such that there is a potential for spread of contamination which the user has not recognised or dealt with, Do not put yourself at risk. Step back and contact your RPS or an experienced RSR inspector for support/advice. (See also section 4 of Chapter 4.)

3.4 4 Unauthorised disposals. If there is evidence that unauthorised disposal of waste sources may have occurred, obtain as much information as possible (having considered issuing PACE Code B Notice). Discuss possible further action with an experienced RAS inspector.

4. Inspection Details Based on Compliance with the Registration Certificate.

In order to help give some order to the inspection, the following copy of the Registration template has been marked up *in italics* (see summary list below) to illustrate the sorts of points you should be looking for. The template is for closed sources which will make up the majority of sources that you will inspect. The other type of certificate that you may encounter is that for mobile (closed) sources; some aspects where this differs are described at the end of this section.

List of notes in italics:

a. Title sheet - requirement to display the certificate;
b. Title sheet - check registered name and address;
c. Certificate (Page 2) - check registered name and address;
d. Schedule 1, para 3b - check display of name of responsible person;
e. Schedule 1, para 4b - check labelling of sources;
f. Schedule 1, para 8b - check source containers, source stores and labelling;
g. Schedule 1, para 11 - check for name changes and/or cessation of use;
h. Schedule1, para 12 - check operator's records;

i. *Schedule 2, para 1 - check number and type of sources against the registration;*
j. *Schedule 2, para 1 - check activities of sources against the registration;*
k. *Schedule 2, para 2 - check that sources are kept/used only as registered.*
l. *Schedule 2, Footnote - reminder of Exemption Orders.*

ENVIRONMENT AGENCY

Note a: It is a requirement under section 19 of the Act that this whole document is displayed at all times on the premises in a prominent position, eg a works notice board or with the company's HSE documentation.

RADIOACTIVE SUBSTANCES ACT 1993

CERTIFICATE OF REGISTRATION
AND
INTRODUCTORY NOTE

CLOSED SOURCES

COMPANY NAME
Note b: Name/address must be checked

REGISTERED PREMISES LOCATION

REGISTRATION NUMBER

INTRODUCTORY NOTE

IN 1. This Note does not form part of the Certificate of Registration.

IN 2. The following Certificate contains details of a registration of the specified premises by the Environment Agency under the provisions of Section 7 of the Radioactive Substances Act 1993 ("the Act"). The registration permits the keeping and use of radioactive materials on one specified premises.

The Certificate of Registration includes a signed Certificate together with two Schedules. Schedule 1 contains standard conditions applied to all holders of such registered sources and Schedule 2 contains details of the sources, the purposes for which they are used, any modifications, additions to or deletions of the standard conditions in Schedule 1 and notice of cancellation of any relevant registration under Section 12(2) of the Act.

IN 3. The Radioactive Substances Act 1993 is an Act of Parliament consolidating the Radioactive Substances Act 1960 and all subsequent amending legislation.

The Act is concerned with the control of radioactive material and any subsequent accumulation and disposal of radioactive waste. The conditions attached to the registration are concerned with the control and security of the radioactive sources.

IN 4. The accumulation and disposal of any radioactive waste associated with the use of this source and its disposal at the end of its useful life will require to be within the terms of Sections 13 and 14 of the Act. It will require appropriate authorisation under those Sections unless covered by an Exemption Order such as the Radioactive Substances (Waste Closed Sources) Exemption Order (SI/1963/1831).

IN 5. The registration does not permit contravention of any other enactment or any order made, granted or issued under any enactment; nor does it permit any contravention of any rule of law or breach of any agreement.

In particular any requirements governing the use of radioactive material under the Health and Safety at Work etc Act 1974 will additionally need to be observed.

IN 6. The undertaking to which this certificate relates may use the radionuclides AA-**, BB-** and CC-** for purposes of (xxxxxx xxxx xxxx x xx xxxxx xx xxxxxxxxxx xx xxx xxxxxxxx, xxxxx xxxxxxxxxx xxxxxx).

ENVIRONMENT AGENCY

RADIOACTIVE SUBSTANCES ACT 1993

Registration - Closed Sources

<<User>>

<<Reference Number>>

This certifies that the Environment Agency in exercise of its powers under Section 7 of the Radioactive Substances Act 1993 ("the Act") has registered

<<Name of User>>
("the user")

whose Registered Office (or Principal Place of Business) is
Note c: It is important to check that the registered name and address are correct. Any specific enforcement action may be prejudiced if the details are incorrect.
<<Registered Office>>

to keep and use radioactive materials closed sources containing the radionuclides and associated materials as described
in the second column of the table in paragraph 1 of Schedule 2 to this certificate on premises used by him at

<<Address of Premises>>

subject to the limitations and conditions in Schedule 1 to this certificate as modified by paragraph 4 and any subsequent paragraphs of Schedule 2.

Signed ....
<<Name of Authorised Person>>
Authorised to sign on behalf of the Environment Agency

Dated the ....

Schedule 1

STANDARD CONDITIONS AND LIMITATIONS
PURPOSES FOR WHICH REGISTERED SOURCES ARE KEPT OR USED

1. The user shall keep or use the registered sources only for the purposes specified in paragraph 2 of Schedule 2.

MAXIMUM NUMBERS AND ACTIVITIES OF SOURCES

2. The user shall ensure -

a. that the number of registered sources, excluding those being held for the purposes of replacement, does not exceed the relevant number specified in the first column of the table in paragraph 1 of Schedule 2; and -

b. that the activity of registered sources does not exceed the relevant activity specified in the third column of that table. -

SUPERVISION OF REGISTERED SOURCES

3. The user shall ensure -

a. that the keeping and use of the registered sources are supervised by a person competent and able to secure compliance with the limitations and conditions specified in this certificate; and -

b. that the name of the person supervising the keeping and use of registered sources is clearly displayed with the copy of this certificate posted on the premises as required by section 19 of the Act. -

Note d: The person responsible for compliance with the registration should be clearly identified and his or her name displayed publicly. His or her training and experience should be ascertained during the inspection.

MARKING OF REGISTERED SOURCES, ARTICLES AND CONTAINERS

4. The user shall ensure -

a. that any article which incorporates or consists of a registered source is legibly engraved, stamped or otherwise suitably marked with an identification number or other distinguishing mark, the word 'Radioactive' and the ionising radiation symbol conforming with BS 3510:1968 or ISO 361; and -

b. that any container in which a registered source is kept or used is legibly engraved, stamped or otherwise suitably marked with -

i. an identification number or other distinguishing mark;
ii. the date of receipt of the source;
iii. the name and activity of each radionuclide (excluding decay products) contained in the source on the day of receipt; and
iv. the word 'Radioactive' and the ionising radiation symbol conforming with BS 3510:1968 or ISO 361.

Note e: The containers and/or the sources themselves should be marked such that they are readily identified as containing radioactive material (including the trefoil symbol) and suitably labelled to permit identification of each individual source against the records. The inspecting officer needs to use judgement to take a reasonable approach, eg with (physically) very small sources where the marking of the container could be sufficient in itself.

KEEPING AND USE OF REGISTERED SOURCES

5. The user shall not lend or let on hire a registered source, or cause or permit it to be lent or let on hire except to a person who is registered under the Act to keep or use such a source. -

6. The user shall ensure that registered sources are not modified and shall so far as is reasonably practicable ensure that they are not damaged.

7. The user shall so far as is reasonably practicable prevent -

a. the loss of any registered source; and

b. access to any registered source by any person not authorised by the user.

8. The user shall so far as is reasonably practicable ensure that each registered source is kept either -

a. under continuous surveillance; or

b. in a suitable container in a suitable store both of which -

i. are so constructed, maintained and used as to prevent the loss or unauthorised removal of the source;

ii. are constructed of non-combustible materials;

iii. do not contain nor are located close to any corrosive, explosive or flammable material; and

iv. are clearly and legibly marked with the word 'Radioactive' and with the ionising radiation symbol conforming with BS 3510: 1968 or ISO 361.

Note f: The container should be secure and appropriate to the type of source(s). The store must be of solid construction with controlled access. It is also important to check for flammable materials stored in the same room; it is common to see solvents or chemical reagents stored in the same room for security reasons. This is not acceptable - fire or chemical attack could release radioactive material from the sources.
Anti-static devices are generally stored in small wall-mounted safes, supplied by the manufacturer; these must be located away from large solvent/paint stores.

LOSS OR THEFT OF REGISTERED SOURCE

9. If the user believes or has reasonable grounds for believing that a registered source has been lost or stolen he shall -

a. without delay inform the Police and the Environment Agency;

b. so far as is reasonably practicable recover the source; and

c. as soon as is practicable report the circumstances in writing to the Environment Agency.

BREAKAGE OF SOURCE OR ESCAPE OF RADIOACTIVE SUBSTANCE

10. If the user believes or has reasonable grounds for believing that a registered source has been damaged or that any radioactive substance is escaping or has escaped from a registered source he shall -

a. without delay inform the Environment Agency;

b. so far as is reasonably practicable -

i. prevent any further escape; and

ii. minimise the spread of any contamination;

c. ensure that any discharge of radioactive gas to the atmosphere is made in a manner which prevents so far as is reasonably practicable its entry into any building; and

d. as soon as is practicable report the circumstances in writing to the Environment Agency.

CHANGE OF NAME OR CESSATION OF USE

11. The user shall give the Environment Agency not less than 21 days notice in writing of his intention to -

a. change the name of the user; or

b. cease to occupy the premises; or

c. cease to keep or use registered sources on the premises.

Note g: It is all too common for companies not to inform the Agency of changes and don't be surprised if some companies, on inspection, are found to have ceased to keep registered sources.

RECORDS

12. The user shall make on the day of receipt or removal as appropriate, clear and legible records of each registered source showing -

a. the radionuclide present, the date on which it was received and the activity on that date;

b. the identification number or distinguishing mark of the source and of any container in which it is kept or used;

c. so far as is reasonably practicable its location on the premises;

d. if it has been removed from the premises, the date of removal, the activity on that date and the name and address of the person to whom it was transferred; and

e. such other information as an authorised person may require.

Note h: A general inspection of the operator's records should indicate how it views its responsibilities under the Act. The records of the sources will indicate whether leak tests have been carried out; note this on the inspection report proforma. Original receipt records should be checked if available. If the operator regularly exchanges the sources then a log of receipt and disposal must be kept; this must show the activity on receipt and date with source identification, plus the identification and date on which the sources were sent off site and to whom. The general intention here is to see whether the operator is exercising proper control to ensure that sources are not lost or misplaced.

13. The user shall keep, unless notified to the contrary in writing by an authorised person, the records referred to in this certificate and in any certificate referred to in paragraph 3 of Schedule 2 available for inspection at any reasonable time by an authorised person in such a place and in such a manner as an authorised person may require.

14. The user shall supply on demand and without charge such copy or copies of all or part of the records kept as referred to in this certificate as an authorised person may reasonably require.

INTERPRETATION

15. In this certificate -

"activity", expressed in becquerels, means the number of spontaneous nuclear transformations occurring in a period of one second in a radioactive substance;

"authorised person" means a person authorised in writing under section 108 of the Environment Act 1995;

"Bq, kBq, MBq, GBq, TBq and PBq" if used in Schedule 2 are used as abbreviations meaning becquerels, kilobecquerels, megabecquerels, gigabecquerels, terabecquerels and petabecquerels respectively;

"closed source" means an object free from patent defect which is radioactive material because it consists of, or includes, one or more radionuclides firmly incorporated on or in, or sealed within, solid inert non-radioactive material so as to prevent in normal use the dispersion of any radioactive material;

"decay products" means, in relation to any radionuclide, the radionuclides succeeding it in the radioactive series in which it and they occur;

"half life" means the time taken for the activity of a radionuclide to lose half its value by decay;

"maximum activity" in the table in paragraph 1 of Schedule 2 refers to the activities of the specified radionuclides and excludes the activities of any associated decay products which may be present in amounts not exceeding those which could be present through radioactive decay of the specified radionuclides;

"modifications" includes additions, alterations and omissions;

"radionuclide" means a species of atom characterised by its mass number and atomic number and subject to radioactive decay;

"registered sources" means -

i. the closed sources containing the radionuclides specified in the table in paragraph 1 of Schedule 2 and any associated decay products, and

ii. closed sources kept for no longer than two weeks for the purposes of replacing the sources specified in the table in paragraph 1 of Schedule 2 when they are designated as waste;

"Schedule" means a Schedule which forms part of this certificate; and

"the Act" means the Radioactive Substances Act 1993.

Schedule 2

1. REGISTERED SOURCES

Table

MAXIMUM NUMBER OF SOURCES	RADIONUCLIDES AND ASSOCIATED MATERIALS	MAXIMUM ACTIVITY IN EACH SOURCE
The number is a maximum *(see Note i below)*	*The radionuclides are listed here plus, eg, beryllium (non-radioactive) in neutron sources, or depleted uranium containers for higher-activity sources*	*This will be in SI units (ie becquerels and multiples), except for depleted uranium which is quoted in kg.* *(See Note j below)*

***Note i:** From time to time the sources need to be replaced, eg anti-static devices are replaced every six months for paint spraying applications. The operator may hold more than the registered quantity; this is acceptable as long as there is evidence that old sources being replaced are to be returned.*

***Note j:** The activity of registered sources should be checked by inspecting the receipt documentation or inspecting the steel plate on the housing of the source if it is safe to do so. If the activity appears to be in excess of the registered amount, take notes and report to the PIR/RSR inspector.*

2. PURPOSES FOR WHICH REGISTERED SOURCES ARE KEPT OR USED

***Note k:** If there are any signs that the source(s) have been modified or altered for a different use then make notes and advise the PIR/RSR inspector.*

3. CANCELLATION OF ANY OTHER REGISTRATION

[This gives notice in accordance with Section 12(2) of the Act that the Environment Agency has cancelled the registration under Section 1 [(or) 7 (if 93 Act)] of the [Radioactive Substances Act 1960] [or] [Radioactive Substances Act 1993] in respect of closed sources issued to in respect of premises at details of which were contained in the certificate dated and referenced

[or]

[This Certificate of Registration does not include notice of cancellation of any other registration].

4. MODIFICATIONS

Modifications or [None].

***Note l:** Some sealed sources may not be registered because they enjoy conditional exemption under an Exemption Order - for details see section 5 of Chapter 6 and Annex.*

5. Mobile Sources

The most commonly-encountered mobile closed sources are soil density gauges, crop flow devices (combine harvesters) or radiography sources. The general terms and conditions are the same as for (non-mobile) closed sources. However, for inspections, the following should be addressed additionally:

1. The user must keep accurate records of the location of the source and the dates when it is away from the registered base address where the device is normally kept.

2. You should check to ensure that the device is not away from the premises for more than six months. If it is, or has been, consult an experienced RSR inspector - it may be necessary to register the source at its "away" location.

3. Safety care is necessary because some mobile sources may be neutron sources and neutron radiation will in general not be detected by personal dosemeters. The general rule of minimising exposure time therefore applies with particular force in the case of such sources. However, it should normally be possible to check the identity of the sources you are likely to encounter without incurring significant radiation exposure.

6. Exempt Sources

The Exemption Orders (EOs) under RSA93 are summarised in the Annex to Chapter 6, which also outlines the underlying philosophy. This present section gives amplification of aspects of those EOs which you will be most likely to encounter in the course of simple closed source inspection.

Because EOs generally confer (conditional) exemption from registration of relevant sources, it will usually not be known whether they are held at given premises. However, the opportunity should be taken during inspections to ascertain whether any exempt sources are held and, if so, to check whether the conditions of the EOs are being complied with.

6.1 Storage in transit - SI 1962 No. 2646

This allows for the storage of radioactive material contained within a package which is secure whilst in transit by road, rail, sea or air. Such packages may not be held for longer than two weeks, a maximum of five packages are allowed at any one time and the smallest dimension must not be less than 102 mm (4 inches). This EO has more detailed requirements relating to radiation and activity levels which should be studied, and advice may be obtained from an experienced RSR inspector.

Typical examples of premises where this EO may be applied are airport warehouses, seaports and railheads.

6.2 Uranium and thorium - SI 1962 No. 2710

This allows an operator to hold unlimited quantities of material containing up to 4% natural thorium or not more than 2 kg in total of uranium and/or thorium. Examples of use include thorium in alloys (including welding rods, magnesium alloys in the aircraft industry) and uranium metal where its high density is utilised (eg aircraft counterweights) or its high atomic number (radiation shielding, eg containers for higher-activity radioactive sources).

6.3 Smoke detectors - SI 1980 No. 953 amended by SI 1991 No. 477

This allows an operator to hold up to 500 domestic-type smoke detectors eg stocks in DIY stores. It also allows without registration the use of smoke detectors fixed to a building with a total activity less than 4 MBq.

In general, the most likely inspection will be to examine the stock records of a warehouse.

6.4 Gaseous tritium light devices (GTLDs) - SI 1985 No. 1047

This was introduced to allow the widespread application of emergency exit signs using tritium gas in glass tubes as a light source. The EO refers to three classes of GTLDs - Class A articles for smaller applications such as exit signs, Class B articles which may be made up of several sealed tubes, and Class C articles installed in a ship, aircraft or vehicle or equipment intended for use by the armed forces of the Crown.

This EO needs to be read carefully before any inspection work against it is undertaken. There is some concern that the conditions of the EO are not being met in the case of the disposal of GTLDs, particularly those in exit signs (see Chapter 3, section 6.3) and it is possible that illegal disposals of these have taken place in recent years either wilfully or in ignorance of the conditions of the EO.

6.5 Testing instruments - SI 1985 No. 1049

This is concerned with radioactive sources used in conjunction with testing instruments and other low-activity sources.

The EO refers to two classes of source. Class 1 sources are those containing not more than 200 kBq of all radionuclides including decay products. Examples include test sources for radiation monitoring instruments. Class 2 sources may contain higher levels of radioactivity - for details see Table 2 of the Annex to Chapter 6.

Typical applications are in analytical laboratory instruments.

7. At the End of the Inspection

At the end of each inspection, the inspector should make the operator aware verbally of any issues where non-compliance is apparent and that any such issues may be followed up by correspondence or by a further visit.

ANNEX TO CHAPTER 7

RSR INSPECTION CHECKLIST

RSR INSPECTION CHECKLIST			
Inspecting Officer:-		Date of visit:-	
1. Operator's Name:-		2. Registration Number:-	
3. Operator's Address:-			
4. Is the address of the premises correct? Y/N		5. Is there a copy of the certificate on display? Y/N	
6. Is the designated person's name displayed next to the certificate? Y/N		7. Does the operator have receipt documentation for the source(s)? Y/N	
8. Source Information:-	Source activity:	Bq:-	Radionuclide:-
	Identification/serial number:-		
	Manufacturer/supplier:-		
	Reference date:-		
9. Date of last leak test (where required):-			
10. Are storage arrangements satisfactory? security/access/fire/labelling Comments:-			
11. Does the source holder show signs of damage? Y/N Comments:-			
12: Has the operator disposed of any sources since the last inspection? Y/N If yes insert details:-			
13. Does the operator hold any sources which are not mentioned in his certificate? Y/N Comments:-			
14. Does the operator hold any exempt sources? Y/N List all exempt sources:-			
Additional Comments:-			
Inspecting Officer's signature:-		Date:-	

GUIDANCE NOTES FOR RSR INSPECTION CHECKLIST

The purpose of these notes is to provide the background behind the questions in the checklist table and how it relates to the conditions within a certificate. The numbering of these notes corresponds to that in the table.

2. The registration number is always located on the top right-hand corner of the case file. It is common for an operator to have quite large files dating back up to 30 years. You may see several different file numbers; use only the most recent. If necessary, check with the PIR/RSR technical support officer.

4. It is important that the address on the registration is correct and that the operator's name has not been changed. The operator is required to notify the Agency of any change of address or name. A change of legal entity requires a new application supported by a fee.

5. It is a requirement of the RSA93 that the operator displays a copy of the relevant certificate along with the name of the person designated to secure compliance with that certificate. This should normally be displayed on the works' notice board alongside the HSE notice or at the area where the radioactive source is being used.

7. The operator should be asked to provide the relevant receipt documentation for the source(s). This should be a consignment note from the manufacturer or supplier; it should contain the source unique identification, manufacturer's name and the date of manufacture (this may be referred to as the activity date).

8. The sources held on the premises should be listed along with the activity and unique identity number of each source. This information is important in the event of the operator losing the records, eg through fire, or going out of business.

9. The leak testing of most sealed sources every 25 months is a requirement under IRR85. It is not a reqirement of the RSA93 certificate. However, this leak test provides evidence that the source is not leaking and this information is useful as confirmation that the user will not have needed to report breakage of a source as would be required under the RSA93 certificate. If a source is leaking, there is the potential for contamination by radioactive material.

10. The certificate requires the source(s) to be kept securely at all times. Compliance with this condition is generally through the design of the housing with appropriate padlocks and cages to prevent easy access. Operators holding mobile sources should have a purpose-built store room with solid walls or steel cages. Radioactive source stores must be located away from flammable materials such as oil tanks, solvents, etc. (It is not uncommon for operators to store radioactive items in solvent or paint stores, taking advantage of the secure nature of such facilities. As mentioned above, this is not acceptable.) In some cases, operations may be on a 24 hours per day basis and it is then possible to rely on operator presence to ensure security.

11. It is important to look for any signs of damage to the source housing, eg cracks, severe corrosion or securing bolts missing. Note any possible problems and refer to the PIR/RSR team.

12. Check whether the operator has made any disposals of sources since the last inspection. If so, make a note of the sources and their identity and where they were sent for disposal. In general most sources are either returned to a supplier or taken away as waste by a commercial operator who is Authorised under RSA93, eg Safeguard International. The disposal of waste sources is almost always carried out under the terms and conditions of the Waste Closed Source Exemption Order.

14. Ask the operator whether there are on the premises any other radioactive devices held under the conditions of an Exemption Order. If there are, list the sources and check their general state and, where possible, compliance with the relevant conditions of the EO.