THE UNIVERSITY *of* EDINBURGH
Health & Safety Department

Radiation Risk Assessment Guidance

Sealed Sources (inc. HASS)

Document Ref:	**RRAG_02**	**Version No.:**	**1**

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Reviewer(s):	Radiation Protection Committee Members

Date of Issue:	**March 2021**
Next Review Date:	**March 2023**

Summary of key Changes		
Version	*Date*	*Changes/Justification*
01	19/04/2021	First version of the document

Contents

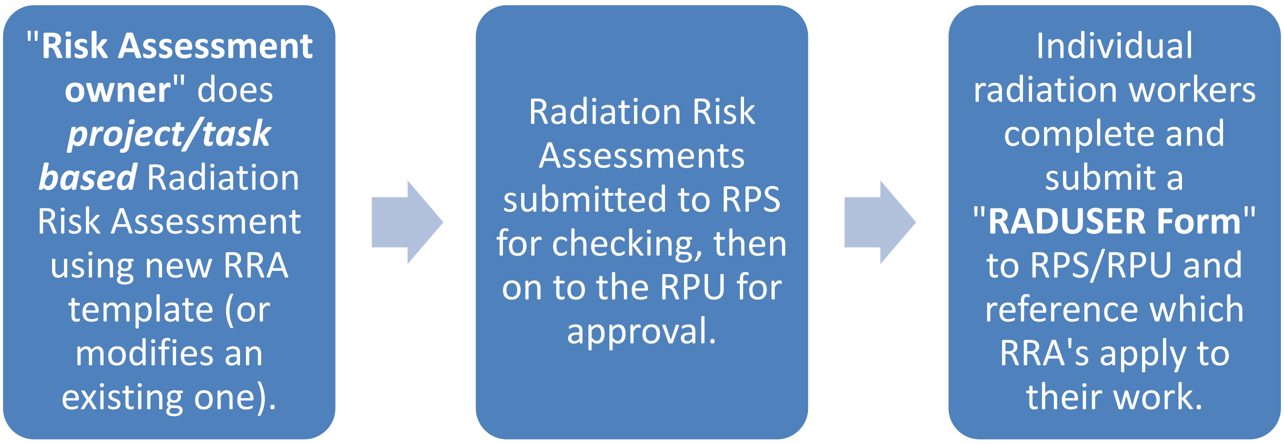
1 Introduction

This Radiation Risk Assessment Guidance Note has been prepared to give staff and students a general appreciation of the kind of hazards and risks that should be considered when working with **sealed (or closed) sources of radioactive material (including High Activity Sealed Sources [HASS])** and to assist them in writing Radiation Risk Assessments (RRA) for their work.

The Ionising Radiations Regulations 2017 (IRR17) and associated Approved Code of Practice (ACoP) [1] are enforced by the Health and Safety Executive (HSE). Regulation 8 of IRR17 requires employers to carry out a 'suitable and sufficient' assessment of the risks, for both routine and reasonably foreseeable accident situations, when working with ionising radiation. In order to be considered 'suitable and sufficient', the HSE expects all IRR17 ACoP Paragraph 70 (a) to (m) matters to have been considered, where they are relevant, and for the employer to decide on the appropriate next steps/decisions based on the matters in IRR17 ACoP Paragraph 71 (a) to (p), where they are relevant.

In order to meet the HSE's expectations of carrying out 'suitable and sufficient' risk assessments for its work with ionising radiation, the University has adopted a two-tier approach to Risk Assessment. This comprises of:

1. *A Project/task-based Radiation Risk Assessment (RRA); AND*
2. *A Signed individual 'Radiation User Registration (RADUSER) Form'*



Definitions:

A **Sealed Source** is a source containing any radioactive substance whose structure is as such to prevent, under normal conditions of use, any dispersion of radioactive substances to the environment.

A **Closed Source** was a term used by the Environment Agencies pre-2011 to describe sealed sources, homogeneous sources and laminated sources. The term is no longer used in environmental legislation but the University wishes to retain this term and it is taken to mean sources of radioactive material which behave like sealed sources, from a radiation protection perspective, but don't strictly meet the definition of a sealed source (for example a closed vial containing a radioactive liquid, if not being consumed/opened, is better thought of as a closed source rather than an open source as there is no contamination risk under normal conditions of use).

A **High-Activity Sealed Source** is a source whose activity value exceeds the value shown in the EASR Regulations that relate to that radionuclide (Table from EASR copied below):

Activity Levels defining high-activity sealed sources

Radionuclide	***Activity***	***Radionuclide***	***Activity***
Am-241	60 GBq	Pm-147	40 TBq
Am-241/Be	60 GBq	Pu-238	60 GBq
Cf-252	20 GBq	Pu-239/Be	60 GBq
Cm-244	50 GBq	Ra-226	40 GBq
Co-60	30 GBq	Se-75	200 GBq
Cs-137	100 GBq	Sr-90 (Y-90)	1000 GBq
Gd-153	1000 GBq	Tm-170	20 TBq
Ir-192	80 GBq	Yb-169	300 TBq
Any other radionuclide	The D-value defined for that radionuclide [2]		

1.1 Project/task-based Radiation Risk Assessments

The aim of this Radiation Risk Assessment Guide is to provide staff and students with a reference document containing useful information on how to complete a project/task based Radiation Risk Assessment using the Radiation Protection Unit (RPU) RRA template. The RRA template can be found on the Radiation Protection Unit (RPU) website under Risk Assessments at:
https://www.ed.ac.uk/health-safety/radiation-protection/radiation-protection-management

By completing the Risk Assessment in this way, the significant findings of the risk assessment are recorded to demonstrate that it is suitable and sufficient. If applicable, e.g. for unsealed sources, the RRA template also includes a section to record the estimates of radioactive waste disposed of to each of the permitted disposal routes.

Project/task-based Risk Assessments must be reviewed every two years.

1.2 Radiation User Registration (RADUSER) Form

Each use of radioactive material must be justified therefore the radiation user must record on their individual RADiation USEr Registration (RADUSER) Form *why* they need to use and work with the radioactive material covered by the Radiation Risk Assessment. This ensures *each use* of radioactive material is justified; as required by IRR17 and the Environmental Authorisation (Scotland) Regulations 2018 (EASR).

The RADUSER form is also used to:

- Record details about the individual working with the radioactive material;
- Ensure persons have had the required training to carry out the work;
- Ensure that the RPSs are aware of the work;
- Ensure the University RPU is aware of the work and has advised on any personal dosimetry requirements or any other control measures;
- Ensure the University has notified, registered or had consent from the HSE about the work being carried out;
- Ensure the work will not exceed any of the limits or conditions in its authorisations issued by the SEPA;
- Record any additional *task-specific* control measures that have been taken to further reduce the risk; these additional controls, if applicable, supplement the project/task-based risk assessment;
- Ensure any especial risks have been accounted for where they are necessary (for example, a pregnancy review section is included on the form);

2 Justification of work with ionising radiation

Three basic principles apply when working with, or planning to work with, ionising radiation:

1. Justification (benefit must outweigh risk)
2. Optimisation (keep doses as low as reasonably practicable – ALARP)
3. Limitation (keep doses below legal limits)

The University must apply these basic principles in its work with ionising radiation. Justification is a fundamental requirement of radiation protection and a balance must be struck between the potential benefits of the work with radiation against the potential harm from it. Justification can be thought of as a two-stage process:

STEP 1: Justify the *class* or *type* of practice involving ionising radiation; and

STEP 2: Justify each individual *use* of ionising radiation.

STEP 1:

This process of justification is the process of ensuring that before any new class or type of practice involving ionising radiation can be introduced in the UK, the Government must first assess it to determine whether the individual or societal benefit outweighs the health detriment it may cause. A good recent example of this is the use of x-rays in sports medicine to monitor athlete's performance. The current list of *justified practices* can be found on the .gov.uk website and the relevant regulations are the *Justification of Practices Involving Ionising Radiation Regulations 2004*, as amended, 'JPIIRR' 2004.

All current work at the University is expected to be justified in accordance with the above regulations but it is possible, that due to research, new practices may be planned. A list of justified practices, relevant to the University's work with ionising radiation, is shown in 2.1 below and is reproduced in the Radiation Risk Assessment template. The box relevant to the work covered by the risk assessment must be ticked by the Risk Assessor. If the work proposed to be carried out under the risk assessment is not listed, then users are directed to contact the Radiation Protection Unit radiation@ed.ac.uk in the first instance.

STEP 2:

This is the process of ensuring that risks are optimised and no radioactive waste is unnecessarily generated; i.e. the process of deciding 'Do you actually need to do the work?'. As this is an individual decision, determined for each individual working with ionising radiation on a case-by-case basis, it cannot be recorded on the project/task-based Radiation Risk Assessment. Individuals must therefore record a statement of justification on their RADUSER Form. A space to make this statement of why they need to use radioactivity is included in the RADUSER form template.

2.1 List of justified practices relevant to University work

The table below contains an abridged list of existing classes or types of practice that are relevant to the University's work with ionising radiation.

#	Area	Class or type of practice
5.	Production of radioisotopes	Manufacture of radioisotopes using nuclear reactors & accelerators.
6.	Production of radioactive products	Manufacture of radioactive sources, substances & radiopharmaceuticals.
7.	Non-destructive testing	Use of radioactive sources, substances & radiation generators for radiography.
9.	Radiation processing of products	Use of gamma, x-ray or electron beam radiation sources to reduce bacterial levels, sterilise, disinfect or modify materials.
11.	Detection & analysis	Use of sealed sources & x-ray generators for analysis.
15.	Safety Devices	Use of ionising radiation in smoke and fire detectors and other safety instruments.
17.	Equipment producing ionising radiation incidentally	Use of electron beam welders, electron microscopes, radar, thermionic valves, cathode ray tubes, ion implantation machines & high voltage switchgear.
18.	Radioactive tracers	Use of radioactive tracers for medical or biological techniques.
23.	Medical & biomedical research	Use of ionising radiation in radiography, fluoroscopy, interventional radiography, computed tomography, in-vivo nuclear medicine, in-vitro nuclear medicine, teletherapy, brachytherapy & neutron activation analysis.
25.	Diagnosis & therapy - Veterinary	Use of ionising radiation in radiography, fluoroscopy, computed tomography, in-vivo nuclear medicine, in-vitro nuclear medicine, teletherapy & brachytherapy.
26.	Teaching, including further & higher education & training	Use of radioactive sources, substances & radiation generators.
28.	Ionising radiation metrology	Use of calibration sources in the testing of equipment.
29.	Transport of radioactive material	Transport of radioactive material by road in accordance with ADR
30.	Use of Uranium and Thorium (other than for its fertile, fissile or radioactive properties)	Use of Uranium and Thorium compounds as laboratory reagents. Other uses of Uranium and Thorium other than for their fertile, fissile or radioactive properties.

Notes:

1. *# is the number of the justified practice from Annex 2 in the JPIIR Regulations 2004.*
2. *Practices involving medical diagnosis and treatment are deliberately excluded from this list as the University must involve a medial radiation protection professional. Contact radiation@ed.ac.uk for more information.*

3 Risk Assessment – Approved Code of Practice Paragraph 70

3.1 (a) The nature of the sources of ionising radiation to be used, or likely to be present, including accumulation of Radon in the working environment

What the HSE expects	Further Guidance
• List all of the radionuclides being used and give a description of their physical form.	• Consider all of the radionuclides, including any radioactive daughters, in the sealed sources that will be covered by the Risk Assessment and their construction. The vast majority of sealed sources at the University are solid form. • All of the University's irradiators contain one or more HASS sources of Caesium-137 in solid form.
• Maximum energies and emissions	• Sealed sources come in many forms and radioisotopes of all types can be made into sealed sources. Their emissions are effected by the type of encapsulation used as sometimes the construction of the source can shield one type of radiation but permit another to be emitted. For example, Caesium-137/Barium-137m emits both a beta particle (from the Caesium-137) and a gamma ray (from the Barium-137m) but sealed sources of Caesium-137 are normally constructed so that the beta particle does not escape from the source such that they are used as gamma only sources. • Consider the maximum energies emitted from the sources you use, the type of emission (e.g. Alpha, Beta, Gamma, etc), and the physical and biological half-life, target organs, range in air, etc. • It may be useful to include a datasheet of the radionuclides used in an Appendix to the RRA like the ones found in '*The Radionuclide and Radiation Protection Handbook 2002*'. A copy of the Handbook can be downloaded for those in academia at the link here: https://academic.oup.com/rpd/article/98/1/1/1679556
• Typical and maximum activities and activity concentrations likely to be used	• Typically sealed source activities are known at the point of purchase and are supplied with a calibration certificate with an associated activity reference date. Software such as radpro calculator or traditional activity equations, see Section 8.2, can be used to determine the current activity of a sealed source. • For sealed source irradiators, the activity of the source(s) within the irradiator is usually written on the unit.

What the HSE expects	Further Guidance
	• For new work, the lowest radiotoxicity source should be selected, with the lowest activity, attendant with the desired purpose of the task.
• Radon assessment (if required)	• Check whether the work is being done in a Radon affected area here → www.ukradon.org. • If the building/lab/etc. is NOT in a Radon affected area, and the work is not in a basement, no further Radon measurement is required. State this in the RRA. • If the building/lab/etc. is NOT in a Radon affected area, and the work is in a basement, a Radon measurement is recommended. The University carried out Radon measurements in all its basements in 2019 and all results were found to be below the Action Level (300 Bq/m^3). ○ Contact the RPU to confirm if your building was included in the RPU check. If it was, include this in your Radiation Risk Assessment. • If the work IS in a Radon affected area, then it may be necessary to further check the Radon levels within the immediate working area. See: https://www.ukradon.org/services/address_search

3.2 (b) Estimated radiation dose rates to which anyone can be exposed

What the HSE expects	Further Guidance
• Estimate dose rates and doses to which anyone can be exposed.	• Exposure to ionising radiation can occur at various points during the planned work, both from routine and accident situations). Record the estimated doses and dose rates in Appendix 1 of the RRA template for routine and accident situations. Useful data to assist with these dose and dose rate estimates can be found in section 8.1 of this document. • Remember, radioactive sources should **NEVER** be held in bare hands. The IRR17 Approved Code of Practice (ACoP), which has a legal standing, advises in paragraph 98 that *sealed sources should not be directly held or manipulated in the hand if it is practicable for the task to be completed by other means*. It

What the HSE expects	Further Guidance
	should **always** be practicable at the University to avoid handling sealed sources as they can be held/manipulated by tweezers, tongs, or other such long-reach tools. • Therefore, in almost all cases, a person's hands shouldn't need to be closer than 10cm to a sealed source (the only exception to this is where the skin of the hand is unlikely to receive a significant dose rate). • Sealed Sources being manipulated on a benchtop, or held at 'arm's length', are assumed to be approx. 30cm and 50cm from the torso respectively (i.e. from the 'whole body'). • For Sealed Sources work, consider doses to the whole body, the extremities/skin (e.g. hands), and the lens of the eye (if applicable). In most cases, it is also worth considering doses to pregnant workers who may work with, or come into contact with, the sources; further information is given in 5(e). • Consider ALL persons that could be exposed from the work. An example list is given in the RRA template of the type of persons that could be exposed but this is not intended to be exhaustive. • In order to comply with IRR Reg 12(3), each RRA must include an estimate of the dose to members of the public from the proposed work. • **Include estimated doses from ALL tasks (routine and accident). For work with sealed sources routine tasks could include storage of the source(s), handling/use of the source(s), selection of the source(s), transport of the source(s), source inventories/accounting, etc.**

• Consider both routine and accident situations.	• As this part of the RRA can involve a number of different steps/stages, estimated doses and dose rates should be recorded in Appendix 1 of the RRA Template.
	  ○ Part 1 should be used to record the estimated doses to all persons affected by the work from *routine tasks*.
	  ○ Part 2 should be used to record the estimated doses to all persons affected by the work from *reasonably foreseeable accident situations*.
	• Consider the activity of the sources used, their emissions, the length of time spent doing each task, the distance from the source and whether there is any shielding in place (*and how effective that shielding is*).

What the HSE expects	Further Guidance
	○ For example, a user may wish to use a sealed source in an experiment. There may be a greater initial dose rate and risk from the collection, handling and transfer of the source(s) to the experimental apparatus, but when that source or sources is in position, the risk is very low due to the shielding provided by the apparatus and greater distance between the user and the source; particularly where the sources may be left in place for long periods of time. • Further guidance on how to estimate doses from various tasks is given in Appendix 1 of this document.

3.3 (c) The likelihood of contamination arising and being spread

What the HSE expects	Further Guidance
• Consider how contamination can arise.	• Sealed Sources remove the risk of contamination by enclosing the radioactive substance in a robust capsule. In a similar way, by definition, closed sources should also remove the contamination risk. • Therefore, under normal conditions of use, there should be no risk of contamination arising and being spread from the use of sealed or closed sources. • Having said that, particular care should be taken when using sealed sources designed to emit alpha radiation as these sources, by their very nature, must have a delicate containment to allow the alpha particles to be detected away from the surface of the source.
• Consider how contamination could be spread outside the working area.	• For sealed or closed sources used where there are valid leak tests in place, the risk of contamination arising and being spread out of the area is very low. • Area contamination monitoring does not normally need to be carried out for sealed sources work. • Area contamination monitoring should be carried out in some cases for closed sources work; for example, a jar of uranyl acetate sitting in a cupboard could be classed as a Closed Source but when in use, you would want to check the working area after the work to look for contamination arising.

What the HSE expects	Further Guidance
	• Although the risk of contamination is very low, it is recommended that persons working with sealed and closed sources carry out handwashing after their work as this is considered good lab practice.

3.4 (d) The results of any previous personal dosimetry or area monitoring relevant to the proposed work

What the HSE expects	Further Guidance
• Is there any results from previous dosimetry that could support the estimates in this risk assessment?	• If a similar task or operation to the one being assessed has been carried out in the past, and those carrying out that task had been subject to personal dose monitoring, then those results might help to estimate the doses for this new risk assessment. • Consider any previous results from whole body dosemeters, extremity dosemeters, biological monitoring and from any Electronic Personal Dosemeter (EPD) campaigns carried out. • One of the duties of an RPS is to collate the dose information for work in their area; it may be worth asking your RPS about any dose results from persons in your area doing similar work. • If personal dosimetry results are available for similar work in your area, record the average and highest results for each year from the last 3-5 years in the RRA. • In the majority of cases, personal dosimetry is not normally required for work with Sealed Sources and HASS however, if persons work with unsealed AND sealed sources, there may be personal dosimetry results available covering both uses which demonstrate low doses for the proposed work.
• Results from any previous area monitoring	• There may have been environmental area monitoring or RPU radiation surveys carried out with the sealed sources in their storage or when in equipment. For example, there may be dose rate or dose data available for sources held in storage from a survey of the source store or for when sources are in use in experiments or equipment from RPU or RPS surveys of that equipment.

3.5 (e) Advice from the manufacturer or supplier of equipment about its safe use and maintenance

What the HSE expects	Further Guidance
• Consider any specific advice provided by the manufacturer on the Sealed Sources safe use.	• Small sealed source manufacturers may also supply advice on the source's use at the point of purchase. • Manufacturers may also provide additional advice on how to leak test their sealed source; for example: ○ Gas Chromatographs with Electron Capture Detectors containing Nickel-63 sources cannot be directly leak tested and manufacturers may provide advice on how/where to leak test. ○ Liquid Scintillation Counters containing sealed sources of Barium-133 or Caesium-137 are also unlikely to be able to be subject to a direct leak test and the manufacturers manual may direct you to where the indirect leak test should be conducted. ○ Atypical sources. An example might be an alpha source where you need to take extra care during leak testing so as not to damage the very delicate encapsulation. • All new Sealed Sources should come with a Recommended Working Life (RWL) from the manufacturer. Universities often use sources for long periods of time; sometimes well past the RWL of the source. In these cases, all sealed sources used beyond the RWL should be recorded in the risk assessment. ○ Where the supplier or manufacturer does not specify an RWL, a review should be carried out within 5 years of manufacture. • As part of the leak testing arrangements, the University RPU carry out a review of the source condition for sources used beyond their RWL. A time limit is set on its continued use, usually up to the next scheduled leak test, where a further review of the source is carried out.
• Additional advice for HASS sources (e.g. irradiators)	• For the HASS sources in irradiators, there is likely to be manufacturer's guidance on the safe use of the equipment. In all cases, there MUST be a service contract in place with the manufacturer or their agent to carry out periodic service checks of the equipment to ensure it remains in good repair. • In most cases, the University's HASS sources will also be supplied with a Special Form certificate. The Special Form certificate allows the source(s) to be transported with less risk on the road/air/sea etc. These Special Form certificates will have an expiry date and this should be noted on the Risk Assessment. If the

What the HSE expects	Further Guidance
	Special Form certificate is beyond the expiry date, direct contact with the manufacturer should be made in order for this to be reviewed and extended.

3.6 (f) Engineering control measures and design features already in place, or planned

What the HSE expects	Further Guidance
• What engineering controls are in place, or planned, to ensure exposure of persons are kept as low as is reasonably practicable (ALARP).	• General Health and Safety legislation, as well as IRR17, requires the adoption of a hierarchy of control measures when carrying out risk assessments. • Once a decision has been made to work with radioactive material or work with radiation, the primary control measure for reducing exposures to ionising radiation is *engineering controls and design features* (e.g. shielding and containment) supplemented by appropriate *safety features and warning devices* (e.g. interlocks, pre exposure signals). • Engineering controls and design features are those that are normally *built-in* control measures such that the facility, device or work cannot proceed if they are not in place. For small sealed sources, examples of engineering controls might be the source encapsulation preventing the spread of contamination and/or reducing the external dose rate.

• Engineering controls for HASS sources (e.g. irradiators)	• For HASS (e.g. irradiators), or situations where there are high accessible levels of radiation, there are a number of engineering controls, safety features and warning devices that may be in place to reduce the risk of exposure. For example:
	  ○ Fixed shielding to reduce the external radiation dose rate outside the equipment/source housing to levels which are as low as reasonably practicable. Where persons are expected to stand to operate the equipment, the external dose rate should not normally be more than 3 μSv/h and in most cases should be around 1 μSv/h or less.
	    ▪ Dose rates outside equipment such as irradiators can be found on the RPU survey. Contact the RPS for further information.

What the HSE expects	Further Guidance
	▪ A dose rate monitoring instrument, fixed to the wall, can act as an additional control to monitor for enhanced radiation levels. ○ Access panels to areas of higher radiation levels may be fixed down, such that they require a tool to open them, or fitted with an interlock. The interlock must be interlocked to the source-moving mechanism such that the source retracts when the interlock connection is broken. ○ Large enclosures may use interlocks, or other appropriate security measures, to prevent access to the enclosure when the source is exposed. ○ Where large enclosures are used, an automatic warning signal must be used to indicate when the source is about to be exposed. If this warning signal fails, the source must withdraw to a safe position. If the failure occurs before source exposure, the source should be prevented from moving to the exposed position (i.e. fail to safety). ○ A sufficient number of emergency stops is required for large enclosures where high dose rates are accessible. These must be clearly labelled and tested at regular intervals.

3.7 (g) Any planned systems of work

What the HSE expects	Further Guidance
• After engineering controls have been considered and implemented where practicable, systems of work, normally incorporated into the Local Rules, should be followed.	• Engineering controls are controls that are built-in and intrinsic to the work. Any control measure that can be by-passed, e.g. a person can choose not to use it or follow it, is a procedural control. • 'Systems of work' are essentially a list of instructions or *procedural controls* to be followed by employees to restrict their exposure to ionising radiation. For sealed sources work, these procedural controls can be included in the Local Rules (which can cover the work with a number of sealed sources). • It is expected that in work with sealed source, the list of procedural controls will be considerably longer than the engineering controls due to the type of work being carried out.

What the HSE expects	Further Guidance
	○ Procedural controls relevant to work with sealed sources are listed in 5.1 and 5.2 covering IRR17 ACoP 71(a) and 71(b) which can be used to draw up the Local Rules.
• Are any 'Permit-to-Work' arrangements required?	• 'Permit-to-work' (PTW) arrangements are a strict set of management controls on how a certain work task will proceed, how it will be done and how it will be supervised to ensure persons exposure to radiation and radioactive material is kept as low as is reasonably practicable. • The PTW also ensures the satisfactory restoration of normal protection measures on completion of the works, including all engineered safety features and warning devices. • For sealed sources work at the University, it is unlikely that permits-to-work will be required however contact the Radiation Protection Unit if you require further information. • An example of a potential permit-to-work situation might be the work on an irradiator to correct a fault with the source-rotating mechanism which requires some of the shielding to be removed around the source. The PTW would ensure that this is done safely and that all shielding removed is replaced and that all other engineering controls and safety features are returned to their normal state. It is likely that this wouldn't be done by University staff.

3.8 (h) Estimated levels of airborne and surface contamination likely to be encountered

What the HSE expects	Further Guidance
• If there is an airborne risk, what levels might be found?	• Provided sealed sources are leak tested at suitable intervals, there should be no risk of any airborne contamination during *normal* conditions of use however, the airborne risk may need to be considered for accident situations (for example a fire). • Sealed sources that are commercially available in the UK are subject to an ISO classification scheme (i.e. ISO 2919 [3]) which tests their performance in a number of areas; including thermal stress. The table below is an excerpt from that scheme:

What the HSE expects	Further Guidance

	Class					
Test	**1**	**2**	**3**	**4**	**5**	**6**
Temperature	No test	-40°C (20min) +80°C (1h)	-40°C (20min) +80°C (1h)	-40°C (20min) +400°C (1h) And thermal shock 400 to 20°C	-40°C (20min) +600°C (1h) And thermal shock 600 to 20°C	-40°C (20min) +800°C (1h) And thermal shock 800 to 20°C

- The source ISO classification number for the temperature test can be used as a screening tool to give a preliminary assessment of the likelihood of release of active material during a fire. This test information can be found on the paperwork supplied with the source.
- It would be conservative to assume that any source not tested to Class 6 (800°C) should be regarded as likely to fail and release some fraction of material in a fire, irrespective of the material of manufacture.
- The table below gives some published data for airborne release fractions [4] for some reasonably foreseeable accident scenarios involving sealed/closed sources:

Scenario	Release Fraction (RF)
FIRE - Liquid source (e.g. closed source vial)	100%
FIRE – Solid sealed source (ceramic/enamel)	<1%
FIRE – Solid sealed source (stainless steel/aluminium)	<5%
FIRE – source inside Type-A transport package	1 x 10^{-6} x Activity carried [per hour]
FIRE – Am-241 sealed source inside smoke detector	<600°C = 200Bq; ~1200°C = <1%

<table>
<tr><th>What the HSE expects</th><th>Further Guidance</th></tr>
<tr><td></td><td>
<table>
<tr><td>FIRE – radioluminised dials, tritium light sources</td><td>100%</td></tr>
<tr><td>FIRE – Uranium powder or other thin metallic powder/foil/wire</td><td>100%</td></tr>
<tr><td>Free-fall spill[1] 3m - a dropped vial of liquid (e.g. closed source)</td><td>4×10^{-5}</td></tr>
<tr><td>Free-fall spill[4] 3m - a dropped powder (e.g depU powder)</td><td>3×10^{-4}</td></tr>
</table>
</td></tr>
<tr><td>• If there is a risk of surface contamination, what levels could be found?</td><td>• As above, there should be no risk of surface contamination during normal conditions of use of a sealed source provided that it is subject to regular inspection and subject to a regular leak test.
• Accident situations leading to surface contamination from sealed sources, other than fires, are very remote possibilities.
• For closed sources, such as sealed liquid samples, there could be surface contamination risk in an accident situation (for example a dropped source). In these cases, assume the entire contents is released across the immediate area. The section above should also be used to consider the amount of that material which becomes airborne from a free-fall drop.
• Other Closed sources such as powder samples like Uranyl Acetate, may give risk to surface contamination during normal and accident conditions. Refer to the unsealed guidance not for further advice.</td></tr>
</table>

[1] Data taken from "DOE Handbook: Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities" DOE-HDBK-3010-94; 1994.

3.9 (i) The effectiveness and the suitability of PPE to be provided

What the HSE expects	Further Guidance
• When engineering controls and Systems-of-work, e.g. procedural controls, have been implemented, is Personal Protective Equipment (PPE) required to further reduce the risk?	• Personal Protective Equipment (PPE) is not usually appropriate or required when working with sealed sources as there is a very low risk of contamination and other measures, such as engineering controls, should be in place to reduce the external radiation levels. • Persons using sealed sources may choose to wear disposable laboratory gloves when working with the sources and/or carry out hand-washing after their work to further reduce the risk of contamination although it is not strictly necessary.
• How effective is the PPE in protecting against the hazard?	• For high energy gamma emitters like Iodine-131, the effectiveness of wearing lead aprons may not be beneficial. For example, a typical 0.35mm lead apron may reduce the external dose by 10% but, by wearing the lead apron, the time spent in the controlled area could be longer, making the task more cumbersome, and cause musculoskeletal issues. • If a decision has been made not to wear PPE, this should be stated in the RRA. • Lead aprons and lead eye protection will provide more protection against the low-energy photon emitting radionuclides. However, in most cases the engineering controls in place should reduce the external dose rate to levels which are ALARP such that PPE is not required.
• Maintenance of PPE	• Where PPE is supplied to protect against the hazard, it must be checked and maintained to ensure it remains fit for purpose. • Disposable PPE, such as gloves, do not need to be examined if they are not being re-used.

3.10 (j) The extent of unrestricted access to working areas where dose rates or contamination levels are likely to be significant

What the HSE expects	Further Guidance

• Employers must be able to demonstrate how they control access to areas where work with radiation or radioactive material is being carried out.	• Although the regulations say 'significant', this effectively means access must be controlled to <u>any</u> Controlled or Supervised Area.
	• For sealed sources kept in a suitable store, dose rates outside the store are unlikely to be significant and therefore unrestricted access to the surrounding room/lab is normally ok.
	• For sealed sources in use, dose rates may be sufficient to warrant a controlled or supervised area. However this may not always be the case. For example, a sealed source being moved from a shielded pot into some equipment may only present elevated dose rates for a short time.
	    ○ Additional access restrictions to rooms/labs should be put in place when sources are in left in equipment for extended periods along with a warning sign/symbol indicating that a source is present in the equipment.
	• Person's required to enter a Controlled or Supervised Area need to have had sufficient information, instruction and training on the arrangements to be followed in that area to restrict their exposure to ionising radiation; this means access has to be controlled.
	• Physical barriers, e.g. doors and chain-link barriers, and warning signs are part of the measures to restrict access to Controlled and Supervised Areas.
	• However, other measures to ensure access is restricted to areas where sealed sources might be stored or used might include:
	    ○ Swipe-card access allowing only selected individuals to enter the area. Consider how is swipe-card access managed and record this in the risk assessment?
	    ○ Key-control access; If access to the area is key-controlled, who has access to the keys? Is there a list of all key holders kept?
	    ○ If access to the area is by a PIN code, when was this last changed? Is there a list of person's who have been given the PIN code?

What the HSE expects	Further Guidance
	○ Are there different arrangements for during the day and at night? i.e. area locked at night but door to room/lab left open during the day when staff are present. ○ Is the room/lab locked when there is no one present in the room where the sources are kept? • For all the managed access types above, consider who is responsible for 'approving' persons to the list? How are they checked to ensure they have had the appropriate information, instruction and training? Is the list regularly reviewed to remove staff who have left and to add newly trained staff?
• Do people not employed by the University of Edinburgh need to enter or work in the area?	• This could be service personnel, visitors, NHS workers, specialist consultants, etc.; essentially anyone not employed by the University of Edinburgh. • If there are persons from other employers entering your Controlled or Supervised Area then they are referred to as 'Outside Workers' under the regulations. • Their access to Controlled or Supervised Areas needs to be managed as the regulations require the employer in control of the area (i.e. the University) to check various bits of information before they can access the area. This is further discussed in ACoP 71 (k).
• Is the area 'handed over' to a contractor or service engineer?	• In some cases, particularly where equipment is concerned (e.g. an x-ray set or an irradiator), the area is 'handed over' to a contractor or service engineer. • When an area is 'handed over', that employer is then responsible for controlling access to their controlled area and this should be stated in their Local Rules. • If an area is handed over to a contractor or service engineer then this must be recorded. A 'Controlled Area and Equipment Handover form' is provided on the 'forms' area of the RPU website: https://www.ed.ac.uk/health-safety/radiation-protection/radiation-protection-management
• Entry to areas by members of the public and those who do not normally work with ionising radiation.	• For the risk assessment, consider how members of the public, or those who do not normally work with ionising radiation (for example undergraduate students/office staff) could access the working area. Remember, many of the University's buildings are open-access. Arrangements must be put in place to restrict the doses of these persons; further information is given in ACoP 71 (m).

3.11 (k) Possible accident situations, their likelihood and potential severity

See Section 4 below.

3.12 (l) The consequences of possible failures of control measures – such as electrical interlocks, ventilation systems and warning devices – or systems of work

See Section 4 below.

3.13 (m) Steps to prevent identified accidents, or limit their consequences

See Section 4 below.

4 Possible accident situations, consequences and steps taken to prevent/limit them

4.1 Further Guidance

When working with sealed sources, it is reasonably foreseeable that accidents could occur. In order for the risk assessment to be considered ‘suitable and sufficient’, all reasonably foreseeable accidents should be identified, the consequences of those accidents addressed, and the control measures taken to prevent, or limit the consequences of, those accidents occurring.

The Radiation Risk Assessment template aims to record these reasonably foreseeable accidents in a table format so that a record is made of who might be affected by the accidents, what the consequences might be if the control measures failed, the Risk Rating assigned to those accidents (based on the likelihood and severity of those accidents occurring), the steps taken to prevent or limit them and the residual risk from those accidents with the steps/control measures in place. An example snip of the pro-forma table from the RRA is shown below:

#	Reasonably foreseeable accident situation(s)	Who is affected	Effect of failure of control measures	Likelihood	Severity	Unmitigated Risk (H/M/L)	Steps to prevent accident or limit its consequences	Mitigated Risk (H/M/L)	Comments / Notes / Recommendations / Actions
		•	•				•		

Some reasonably foreseeable accidents that could occur when working with sealed sources, their possible effects, and examples of steps that could be adopted to reduce the likelihood and severity of those accidents are given in 4.3 below. Note, this list is not intended to be exhaustive and risk assessors should adapt it to suit their individual circumstances.

Each reasonably foreseeable accident listed in the table should have its potential dose estimated as part of the Risk Assessment. The estimated doses from each of the reasonably foreseeable accidents should be recorded in Appendix 1 of the RRA template under section 8.2.

4.2 Risk Rating (Likelihood x Severity)

Assigning a risk rating is a good way of assessing and comparing risk from different tasks/scenarios. The risk rating is the likelihood or probability of that accident happening, multiplied by the severity of the consequences if that event occurred. For example, it might be quite likely (4) that a small spillage could occur during work with unsealed radioactive material, but the severity might only be minor (2) if the concentration was low and only a small radiation dose could be received which was below a local investigation level.

The Radiation Risk Assessment template includes a matrix, like the one shown here on the right, which should assist you in deciding what the likelihood is, and what is the severity of, any particular accident or incident from your work.

In most cases, the steps taken to prevent the accident, or limit its consequences, should reduce the likelihood and/or severity such that the probability of the accident occurring, after control measures are implemented, are low. However, this may not always be the case. A comments and recommendations column is provided on the RRA template to record any actions taken, or recommendations made, to further reduce the overall risk.

Risk Rating	**Severity**				
Likelihood	**(1) Negligible** *Slight chance injury / background radiation dose*	**(2) Minor** *Minor injury/ dose below investigation levels*	**(3) Moderate** *Three-day injury / dose less than legal limits*	**(4) Major** *Major Injury/ dose > legal limits*	**(5) Extreme** *Fatal / dose > deterministic threshold*
(5) Very Likely *Very likely to occur / regular occurrence*	**(Medium)**	**(Medium)**	**(High)**	**(High)**	**(High)**
(4) Likely *Probable / Frequent Occurrence*	**(Medium)**	**(Medium)**	**(Medium)**	**(High)**	**(High)**
(3) Possible *Possible Occasional Occurrence*	**(Low)**	**(Medium)**	**(Medium)**	**(Medium)**	**(High)**
(2) Unlikely *Remote Rare Occurrence*	**(Low)**	**(Low)**	**(Medium)**	**(Medium)**	**(Medium)**
(1) Very Unlikely *Improbable Remote Occurrence*	**(Low)**	**(Low)**	**(Low)**	**(Medium)**	**(Medium)**

4.3 Examples of typical accidents from working with sealed sources

Note the table shown below is for guidance only and is not intended to be copied verbatim. Risk assessors must consider each individual circumstance relevant to their application.

<table>
<tr><th>Reasonably foreseeable accident situation(s)</th><th>Effect of failure of control measures</th><th>Steps to prevent accident or limit its consequences</th></tr>
<tr><td>• Loss or theft of an IAEA Category 5 sealed source
(Applies to the vast majority of sealed sources at the University except irradiators and a handful of IAEA Category 4 sealed sources. If you are unsure of your sources IAEA category, contact your RPS or the RPU.)</td><td>• It is not possible to reasonably estimate doses to persons as a result of a lost source. Doses should be estimated once the source(s) has/have been found and some actual facts have been determined.
• It is possible that persons, including other staff and members of the public, could receive internal and/or external doses above dose investigation levels set out in the Local Rules or above public dose limits but classification of staff is unnecessary on this basis alone.</td><td>• Sealed sources are kept in suitable stores when not in use which provide adequate physical security;
• Sealed source stores are labelled to warn persons of the contents within;
• If sealed sources are placed in a piece of equipment, for example for an experiment, the person in charge of the sealed source must:
○ Supervised the equipment at ALL times; or
○ Lock the room in which the equipment is located if they leave the equipment unattended for ANY reason.
• A log is kept of sealed source use such that it can identify:
○ Who removed the source from the store;
○ What date and time the source was removed;
○ Where the source is being used (i.e. room number);
○ When the source was returned and by whom;
• Regular checks on the presence of sealed sources (i.e. monthly accountancy);
○ Where possible, efforts should be made to physically observe the source where doses rates allow.</td></tr>
</table>

Reasonably foreseeable accident situation(s)	Effect of failure of control measures	Steps to prevent accident or limit its consequences
		• Regular inventories of sealed sources stores to confirm the contents within match the paperwork (i.e. full annual inventory checks); • Access to areas where sealed sources are kept or used is restricted is through a combination of swipe access/key control/PIN code entry such that only authorised personnel can enter; • Only authorised personnel have access to sealed source stores; • Use of recommended and/or trusted suppliers of sealed source manufacturers to supply and deliver new sealed sources; • To establish a chain-of-custody for handover of radioactive sealed sources delivered to the premises; • To transfer sealed sources immediately to a secure store upon receipt; • Once a loss/theft of a sealed source is confirmed, an investigation is carried out that involves the RPS and the University RPA.

Reasonably foreseeable accident situation(s)	Effect of failure of control measures	Steps to prevent accident or limit its consequences
• Loss or theft of a HASS source *(Also includes additional measures for IAEA Category 4 sources held by the University)*	• It is not possible to reasonably estimate doses to persons as a result of a lost source. Doses should be estimated once the sources has been found and some actual facts have been determined. • It is possible that persons, including other staff and members of the public, could receive internal and/or external doses above dose investigation levels set out in the Local Rules or above public dose limits but classification of staff is unnecessary on this basis alone.	• *Steps as above plus…* • A Site Security Plan is implemented, maintained and reviewed for all sealed sources which are defined as HASS or IAEA Category 4 sealed sources. • Access to areas where HASS are used are further restricted via an alarm system linked directly to the University security department. • Regular checks of the security system ensure that it is maintained in good working order. • Regular inspection of premises by Counter Terrorism Security Advisers (CTSA).
• Fire (*either in the immediate area of the source or involving the source*)	• It is possible that persons, including other staff and members of the public, could receive internal and/or external doses above dose investigation levels set out in the Local Rules or above public dose limits but classification of staff is unnecessary on this basis alone.	• Sealed sources are kept in suitable stores that provide resistance to fires; • Stores allocated to the storage of sealed sources are only used for the storage of sealed sources, their immediate containers and receptacles and any handling/shielding tools or materials. ○ *No equipment or other hazardous substances unrelated to the sealed sources, which could increase the fire loading, is kept in the sealed source store.* • Persons follow normal University fire evacuation procedures; • Sealed sources are returned, where possible, to secure fireproof stores when not in use to minimise the risk of dispersal in a fire;

Reasonably foreseeable accident situation(s)	Effect of failure of control measures	Steps to prevent accident or limit its consequences
		• Attending fire-fighters are informed of the presence of sealed sources in the vicinity of the fire when they arrive; • Following a fire, if there is any doubt as to whether the integrity of any sealed source has been compromised, the University RPA must be consulted to advise on safe re-entry of the building (i.e. to establish dose rate cordons) and to advise on how the source can be checked for damage (i.e. leak test).
• Leaking source during normal operation	• Higher-than-normal external radiation dose-rates are unlikely to arise from a leaking source. • Significant bodily contamination is unlikely once the leakage has been identified, if the normal incident response is followed. • It is unlikely that potential doses arising from contamination before the leak was identified could be reasonably estimated beforehand. Classification of staff is therefore unnecessary on this basis alone.	• Sources are leak tested at regular intervals by the Radiation Protection Unit; • A review of the source condition is carried out at the leak test to reduce the likelihood of leakage occurring during normal use. • Where a leaking source is identified during normal use, all further handling/use of the source is stopped until the RPS and/or University RPA has carried out an investigation; • A contamination survey is carried out to identify the extent of the source leakage; • Leaking sources are confined appropriately until a decision is made on their future use/disposal.

Reasonably foreseeable accident situation(s)	Effect of failure of control measures	Steps to prevent accident or limit its consequences
• Radiation alarm sounds *(i.e. radiation alarms in the vicinity of HASS sources)*	• Higher-than-normal dose rates are possible, but it might not be possible to estimate them to any useful accuracy. • However, assuming that the normal incident response is followed, dose rates will normally be measured at the time of the incident, and doses should not exceed normal operating levels. • Classification of staff is unnecessary on this basis alone.	• The contingency plan within the Local Rules should include steps to obtain further information about the radiation levels without incurring a significant dose; ○ For example, a procedure on where to locate a suitable dose rate meter away from the room/area and how to measure dose rates approaching the room. • If enhanced dose rates do exist, an initial cordon must be set up at a dose rate of 3 µSv/h, adapted to make best use of the building's layout. It might be necessary to sound the fire alarm to evacuate the building. • The RPS must be informed immediately when alarms sound. • Decisions about dealing with the condition that caused enhanced dose rates are then made in conjunction with the University RPU and the source equipment manufacturer.
• Damage to the source or the source enclosure	• Significant external radiation dose-rates are unlikely to arise from a damaged source or source enclosure (unless it is a HASS). • Significant bodily contamination is unlikely if the normal incident response is followed. • Assuming the normal incident response is followed, dose rates will be measured and doses should not exceed normal operating levels. Classification of staff is	• A review of the sources condition, including its receptacle, is carried out as part of the leak test; • When sealed sources are removed from their source store and taken to other areas for use in equipment, they are carried in suitable receptacles such that damage to the source should be minimised if dropped; • If a source is dropped, or if a receptacle is dropped during movement, the RPS must be informed such that a leak test can be carried out.

Reasonably foreseeable accident situation(s)	Effect of failure of control measures	Steps to prevent accident or limit its consequences
	therefore unnecessary on this basis alone.	○ It is preferable that a dropped source or dropped receptacle is not handled until a leak test is carried out but it is accepted this may not always be practicable. ○ For example, if a source is dropped in a corridor, it would be practicable to don a pair of disposable gloves, or use a handling tool if available, to move the source into an adjacent room/area to allow the corridor to be used again; save for maybe covering the immediate drop-zone with a piece of cardboard or tape until the leak test has confirmed no leakage has occurred. • If there has been damage to the source enclosure it is likely that the manufacturers/suppliers will need to be contacted to assess the extent of the damage.
• Breakdown in controls *(i.e. persons not following Local Rules)*	• It is not possible to reasonably estimate doses to persons as a result of them not following local procedures. Doses could be estimated following an investigation when some facts have been determined. • It is possible that persons could receive internal and/or external doses above dose investigation levels set out in the Local Rules but classification of staff is unnecessary on this basis alone.	• Ensure users are provided with appropriate training, which is refreshed at suitable intervals, to allow them to understand and evaluate the risks from the sealed sources they work with; • Give practical, local, instruction on how to handle sealed sources properly how to minimise exposure; • Provide suitable equipment and documentation at source stores to allow the safe handling, transfer, recording, etc. of sealed sources work. • Report and follow-up instances of bad practice.

5 Risk Assessment – Approved Code of Practice Paragraph 71

5.1 (a) The action needed to make sure the radiation exposure of all people is kept as low as is reasonably practicable

<table>
<tr><th>What the HSE expects</th><th>Further Guidance</th></tr>
<tr><td>

- What control measures are in place to reduce the exposure to all persons from EXTERNAL radiation to levels that are as low as reasonably practicable?

</td><td>

EXTERNAL RADIATION

In addition to the control measures referred to elsewhere in this guidance note, the following control measures should be considered to restrict persons from external radiation exposure.

- Selection of which radionuclide(s) to use for Sealed Source experiments by giving due consideration to the radiation type (e.g. gamma, beta, etc.) and main emission energies (i.e. preference given to lower keV radionuclides) such as to minimise, where practicable, radiation doses to all persons;
- Selection of the lowest activity practicable to achieve the desired purpose;
- Disposing of sealed sources as soon as practicable after they are replaced or are identified as being of no further use;
- Using appropriate shielding material for stores containing sealed sources or for their immediate containers based on the type of radiation being emitted from the source(s).
    - Some example shielding materials for the different types of radiation are given in Appendix 1 alongside their total absorption thickness or their half-value layer (HVL) or tenth-value layer (TVL);
- Keeping Sealed and Closed Sources in suitable stores where external dose rates outside the store are kept as low as reasonably practicable but always below 2.5μSv/h;
- Keeping dose rates from Sealed Sources in equipment to levels which are as low as reasonably practicable.
    - Where untrained persons have access to the area around the equipment, accessible whole-body dose rates must be kept below 7.5 μSv/h.
    - If only trained persons can access the area in or around the equipment, accessible whole-body dose rates must be kept below 3 μSv/h but should normally be less.

</td></tr>
</table>

What the HSE expects	Further Guidance

	• Keeping parts of the body, including the hands, as far away as practicable from the source during use;
	• Keeping parts of the body, including the hands, behind protective screens or shielding (where practicable) when not working or manipulating sources;
	• Labelling items of equipment that contain radioactive sources to warn persons of the presence of a radioactive source within;
	• The immediate source containers holding sealed sources must be labelled to indicate the presence of a radioactive source;
	• Ensuring Local Rules instruct persons not to handle radioactive sources with bare hands and encourage the use of handling equipment such as tweezers/tongs/etc.;
	• Where practicable, collimate the beam so that the radiation is being emitted in the direction of its intended target; preferably one fixed direction;
	• If enclosures are used in or around sealed sources to prevent access to high dose rates by persons then access panels or doors must be either fixed down (for example requiring a tool to open) or be interlocked to the source;
	• Personal Protective Equipment to reduce external dose rates is not normally required in sealed sources work;
	  ○ Lead aprons and lead eye protection may be of some limited use in reducing the dose rate in situations where low-energy photons are being used and engineering controls are insufficient – this is expected to apply to very few situations, if any.
	  ○ Disposable laboratory gloves will provide some very limited shielding of low-energy beta radiation where the hands are in very close proximity to the sealed source but this is not normally always appropriate or required;

What the HSE expects	Further Guidance
	For HASS sources, such as irradiators, the following external radiation control measures may be applicable to the equipment being risk assessed: • Shielded enclosures to reduce accessible dose rates to levels which are as low as reasonably practicable; • Utilization of a remote process to move items into the beam path or to move the beam path to the items; • Where a remote process is used as above, ensure the door and/or access panels are interlocked to the source moving mechanism such that the door/panels cannot be opened if the beam is exposed, and the beam cannot be exposed if the door/panels are open; • Signals on the equipment to indicate when a source is being exposed or in the 'moving' phase; • The installation of a fixed radiation monitoring instrument in the room (or adjacent room) to detect enhanced radiation levels in the event of an incident;

• What control measures are in place to reduce the exposure to all persons from INTERNAL radiation to levels that are as low as reasonably practicable?	**INTERNAL RADIATION**
	In addition to the control measures referred to elsewhere in this guidance note, the following control measures should be considered in the risk assessment, where appropriate, to minimise the risk of contamination arising and being spread and to restrict internal radiation exposure.
	• Sealed Sources, which have a valid leak test, remove the majority of the risk of exposure to internal radiation under normal conditions of use. However, there are some additional control measures recommended below for sealed source use which should further reduce the potential for exposure to internal radiation:
	  ○ Ensure sealed sources are not used beyond their leak test date;
	  ○ Follow good laboratory practice and wash hands after working with sealed sources.
	    ▪ If a wash hand basin is not available, or is unlikely to be available close to the working area, disposable gloves could be worn during the work with the sealed source instead;

What the HSE expects	Further Guidance
	○ If a sealed source is dropped, or is thought to have been damaged in any way such that the integrity of the source capsule could be compromised, then do not use the source. A dropped-source incident plan should be included in the Local Rules; ○ Handle sealed sources designed for emitting alpha radiation with extra care as their construction means the encapsulation is likely to be fragile; ○ Store sealed sources in suitable storage areas which are marked with the appropriate signs in accordance with the Health and Safety (Safety Signs and Signals) regulations and reduce the risk of fire; ○ Store sealed sources in suitable containers to minimise the risk of dropping or damaging them; ○ Avoid touching the face, hair or other exposed body parts when working with sealed sources; ○ Covering of cuts/abrasions with waterproof dressings to further reduce the risk of radioactive material bypassing the body's natural defences and getting into the body. • For some closed sources, such as jars of uranyl acetate, if they are to be worked with (rather than simply stored) then they are likely to behave more like unsealed/open sources and therefore control measures more suited to open source work must be considered. See Radiation Risk Assessment Guidance RRAG_01.

5.2 (b) The steps necessary to achieve this control of exposure by the use of engineering controls, design features, safety devices and warning devices and, in addition, to develop systems of work

What the HSE expects	Further Guidance

• Engineering Controls, design features and safety/warning devices	• Regulation 9(2) of IRR17 sets out a hierarchy of control measures for restricting exposure.
	• Consider in the Risk Assessment what *engineering controls and design features* (e.g. shielding and containment) are in place to reduce the likelihood of both external and internal radiation exposures. In addition, there may also be *safety/warning devices* (e.g. interlocks or warning devices) to supplement the engineering controls.
	• For small sealed sources, examples of *engineering controls and design features* normally used to restrict exposure might be the source capsule itself as this would prevent the source from leaking and spreading contamination.
	    ○ Depending on the intended use of the source, the capsule may also shield some *unwanted radiations* (e.g. beta radiation) from being emitted from the source.
	    ○ In addition, the source might be directional; for example more radiation being emitted from one surface, e.g. the 'face', with other sides of the source providing more shielding.
	• For High Activity Sealed Sources, examples of *engineering controls and design features* might be:
	    ○ Shielding in/around HASS to reduce the dose rate to levels that are ALARP;
	    ○ One or more *mechanical* interlocks that prevent the source rotating mechanism from operating when an access door or panel is open;
	    ○ Dose-rate operated interlocks that prevent access until radiation levels are below a safe level.
	• For HASS, there may also be additional *safety features* such as:
	    ○ For example an emergency off switch either on the equipment or in the room;
	    ○ A key operated control panel or locking off system (e.g. Castell trapped-key system);
	    ○ An interlock at the entrance to a room which switches off the equipment or closes a shutter;

What the HSE expects	**Further Guidance**

	• For HASS, there may also be additional *warning devices* such as:
	  ○ Exposure indicators warning persons that the source is in radiating mode;
	  ○ Warning lights indicating equipment is in service mode, for example if a safety feature is disabled;
	  ○ Radiation dose rate area monitoring equipment to provide an audible alarm in the event of a sudden increase in the radiation dose rate.
	• Any control measure that relies on an individual making a choice whether to use it or not is a procedural control; i.e. if they bypass the control measure then no protection is provided.
	  ○ For example, the sealed source *capsule* is an example of an engineering control but the sealed source *container* is an example of a procedural control as the user may forget to return it to the right container or may replace the container with the wrong type etc.

• Systems of work	• Systems of work are essentially the *procedural controls* to be followed by staff to further restrict their exposure to ionising radiation once all the engineering controls have been exhausted.
	• For work with sealed sources, much of these controls should be listed in the Local Rules. Examples of the types of procedural controls to reduce external and internal radiation exposures are given in 5.1.
	• The University RPU have created model local rules for sealed sources work to capture many of the routine procedural controls designed to reduce exposures to ionising radiation. These model local rules can be found here:
	  ○ https://www.ed.ac.uk/health-safety/radiation-protection/radiation-protection-management/local-rules
	• To assist the systems of work, a Permit to Work may be required in situations where strict management controls are required over the conditions in which work will proceed, how it will be done, and how it will be supervised. For example a Permit-to-Work for sealed sources might be required:
	  ○ Where interlocks or other engineered safety devices are by-passed or over-ridden;
	  ○ During routine equipment servicing or maintenance where the equipment is under the control of a service engineer if access to high dose rates is possible;

5.3 (c) Whether it is appropriate to provide PPE and if so, what type is adequate and suitable

<table>
<tr><th>What the HSE expects</th><th>Further Guidance</th></tr>
<tr><td>
What PPE is still required to protect persons from the hazard after engineering & procedural controls have been exhausted.
</td><td>

In the case of work with sealed sources, and closed sources not being used, Personal Protective Equipment (PPE) is unlikely to be appropriate unless you are planning to:

Work with low-energy photons; or
Handle sources emitting low-energy beta radiation without tongs/tweezers etc.

Even when working with the above, engineering controls and safe systems of work should be in place to reduce the risk, predominantly from the external radiation hazard, to levels which are as low as reasonably practicable such that PPE is not normally required to be worn.
Although disposable laboratory gloves may be worn as part of good lab hygiene practice, they are not strictly PPE under IRR17 as they are not being used to restrict exposure to radiation.
Where PPE is still required, the following may be of use:

Lead aprons and lead eye protection may be of some limited use in reducing the dose rate in situations where low-energy photons are being used and engineering controls are insufficient – this is expected to apply to very few situations, if any.
Disposable laboratory gloves will provide some very limited shielding of the beta radiation dose to the hands where the hands are in very close proximity to the sealed source;
Where reliance is placed on the use of PPE, ensure that it is checked and maintained so that it remains fit for purpose;
Where PPE is provided, there must be an appropriate area for it to be stored, topped up and ready for use.

</td></tr>
</table>

5.4 (d) Whether it is appropriate to establish any dose constraints for planning or design purposes and if so, what values will be used

What the HSE expects	Further Guidance
• Dose constraints for routine occupational exposures.	• In most cases, dose constraints are not normally appropriate for routine work in the non-nuclear sector as doses tend to be low. They are not intended to be used as investigation levels once work is planned and underway; they are replaced by Dose Investigation Levels (DILs) in Local Rules. • Therefore, for routine sealed and closed sources work, dose constraints are not normally required.
• Dose constraints for members of the public should not exceed 0.3mSv.	• In order to comply with Regulation 12(3) of IRR17, an assessment of the potential dose to a member of the public from the work must be included in each Risk Assessment. • It is unlikely that most routine work with sealed or closed sources at the University could give rise to a public dose in excess of 0.3mSv. However, consider the use of sealed sources where persons untrained in radiation protection, for example a member of the public or an undergraduate, could come into close proximity to the source or to the equipment containing the source. ○ Although some accident scenarios could give rise to a public dose in excess of 0.3mSv, such as a fire or lost source, a dose constraint is not appropriate in this case.
• Dose constraints for ‘new’ work	• Dose constraints are often considered when planning new facilities or new procedures using radiation or radioactive material. For example, it is quite common to specify a dose constraint when designing and planning a new x-ray room/suite in a building. • It may be useful to specify a dose constraint for some sealed sources work if the technique or experiment is ‘novel’ and doses may be different to other work being done. • Dose constraints for new work help to filter out options for radiation protection that could lead to unreasonably high doses; e.g. if the dose constraint is exceeded, consider other options and control measures to try and reduce the potential dose down further. • If applicable, a common dose constraint selected for workers is around 1mSv and 0.3mSv for all other persons. However, a dose constraint must be selected which is specific to the task.

5.5 (e) The need to alter the working conditions of any employee who declares they are pregnant or breastfeeding

What the HSE expects	Further Guidance
• Employers must make female workers aware of the increased risk to the foetus from work with ionising radiation.	• Female workers are made aware of the potential risk to the foetus from exposure to ionising radiation during the basic radiation training course(s). • If female workers are to work under the risk assessment, it must include the arrangements for pregnant and breast-feeding workers; • Ensure the arrangements in the Risk Assessment (and Local Rules) include *how* and *who* female workers should contact when declaring their pregnancy; ○ Their Line Manager should be their main contact; they are NOT legally required to inform the RPS but it may be easier or more helpful for them to do so. • Further guidance on working with radiation when pregnant or breast-feeding can be found in Radiation Protection Code of Practice RP CoP013 "*Working with Radiation when Pregnant or Breastfeeding*".
• Employers must ensure the dose to the foetus does not exceed 1mSv following the declaration of pregnancy.	• Once informed about an employee's pregnancy, the employer must ensure the dose to the foetus doesn't exceed 1mSv for the remainder of the pregnancy; • This often means that the Risk Assessment for the employee should be reviewed once pregnancy has been declared. A section is included on the RADUSER Form to record this 'review'; • Radiation Protection Code of Practice RP CoP013 gives more guidance on the type of things that should be reviewed as part of the risk assessment; • The Risk Assessment review should be led by the RPS (if they have been informed) or the employee's Line Manager with input from the University Radiation Protection Unit if necessary; • Pregnant workers need not be completely excluded from working with sealed sources as the main risk to the foetus is from internal radiation. ○ Where penetrating external radiation is the main hazard, a 1 mSv dose to the surface of the abdomen is estimated to correspond to a foetal dose of 0.5 mSv. If whole-body doses are estimated to be less than 1mSv from the work, then foetal doses should not be exceeded.

5.6 (f) An appropriate investigation level to check that exposures are being restricted as far as is reasonably practicable

What the HSE expects	Further Guidance
• Employers must include in their Risk Assessment (and Local Rules) an appropriate dose investigation level.	• The Dose Investigation Level (DIL) chosen must be set at a level whereby it allows the employer to monitor whether radiation exposures are being managed As Low As Reasonably Practicable (ALARP). • The level chosen should be set such that the dose is unlikely to be exceeded by persons following appropriate controls to minimise their external and internal radiation dose. • In most cases, persons working with sealed or closed sources at the University should not receive significant radiation doses. • **It is therefore advised that, unless the work involves Classified Persons, the Dose Investigation Level (DIL) for anyone working with sealed or closed sources at the University must not be greater than the levels below in any calendar year:** ○ **1mSv effective (whole body) dose; or** ○ **50mSv to the skin and extremities; or** ○ **15mSv to the lens of the eye.** • Where work with sealed sources is taking place that involves Classified Persons, higher DILs may be appropriate. • Departments may choose to set lower 'action levels'; for example, based on dosemeter wearing periods, so that they can monitor radiation doses throughout the year to ensure a DIL isn't going to be exceeded. These Action Levels can be managed locally by RPSs and within the Local Rules.
• Carry out an investigation if the DIL is exceeded.	• The purpose of the investigation is to trigger a review of the group's, or individual's, working arrangements to consider if doses are being managed as low as is reasonably practicable. • Any dose investigation involving an employee who has exceeded, or who is likely to exceed, a DIL must involve the University Radiation Protection Unit. • A formal report, under IRR Reg 9(8), is required which will include:

What the HSE expects	Further Guidance
	○ Details of the person's routine before and after the incident including any colleagues who worked closely with them over the investigation period; ○ Whether the person had been involved in any other known incidents in which they may have received an unusual exposure; ○ Details of the person's estimated dose over the period being investigated compared with estimated doses of other persons carrying out similar work; ○ Results of any special radiation or contamination surveys carried out in the area after or before the incident to determine if there had been any deterioration in physical control measures; ○ Evidence from the RPS, the individual concerned and from other work colleagues on adherence to local rules or any deficiencies in those Local Rules in light of the incident.

5.7 (g) The maintenance and testing schedules required for the control measures selected

What the HSE expects	Further Guidance
• Instruments and equipment designed to assist and help with ensuring radiation protection measures are controlled must be subject to regular maintenance and testing.	• Some of the control measure employed to reduce radiation exposures from work with sealed sources may rely on equipment, instruments, safety features, warning devices, engineering controls, etc. being maintained and/or tested to ensure they are measuring or functioning correctly. For example: • Interlocks; • Emergency Stop buttons; • Dose rate monitoring equipment; • Regular Irradiator servicing; • Warning lights; • Leak test of source integrity; • If the work carried out as part of your Risk Assessment relies on any of the things above then you should consider, as part of the risk assessment: ○ Who carries out the maintenance? Do they require access to a Controlled or Supervised Area?

What the HSE expects	Further Guidance
	○ Who is responsible for organising the maintenance/testing and how is it organised? ○ Is the maintenance carried out as part of a regular maintenance or service contract? ○ The appropriate interval between maintenance and/or testing to ensure that the control measures relying on it remain adequate. For example this interval may be a manufacturer's recommended interval or an interval stated in the regulations; ○ Who is responsible for ensuring it is carried out on time? • Radiation and contamination monitoring instruments must be subject to an annual periodic check which includes a check of the overall instrument condition and a calibration check. Annual periodic checks are normally arranged by the RPS through the RPU.
• A record must be kept of the examination and tests carried out.	• Ensure the risk assessment includes what records are kept, for example, warning light checks, service reports, instrument test certificates, tests of emergency stops, etc.

5.8 (h) What contingency plans are necessary to address reasonably foreseeable accidents

What the HSE expects	Further Guidance
• If a *radiation accident* is considered to be reasonably foreseeable then a Contingency Plan is required.	• The aim of a Contingency Plan is to restrict exposures that arise from a reasonably foreseeable '*radiation accident*' as far as reasonably practicable. The level of detail within the plan should reflect the circumstances anticipated. • A '*radiation accident*' is defined as an accident where <u>immediate</u> action is required to prevent or reduce the exposure to ionising radiation of employees or any other person. ○ The intention is that the action should be '*immediate*' and should prevent or reduce '*exposures of concern*'. Whilst no value is assigned to this, an '*exposure of concern*' is an exposure which significantly exceeds, or could significantly exceed, normal planned exposures.

What the HSE expects	Further Guidance
	○ As doses at the University are low, an '*exposure of concern*' is taken to be an exposure greater than 1mSv per year; **i.e. Contingency Plans should be written where <u>immediate action</u> is required to prevent or reduce doses below 1mSv.** • Therefore an accident, like those listed in 4.3, may not necessarily lead to a '*radiation accident*' as defined above. Contingency Plans are therefore not always needed for **EVERY** accident situation. ○ An example might be a dropped source scenario where the source container is dropped whilst being carried between labs. It is unlikely that the robust source capsule would suffer such damage in this situation and it would be extremely unlikely to result in any dose to a person let alone *an exposure of concern*. You may decide a dropped source accident does therefore not require a Contingency Plan but you might still describe what to do if it happens in the Local Rules. ○ An example where you would require a Contingency Plan is a lost or stolen source. It is possible that the source is in the possession of a person or persons who are untrained to know what the risks are and could receive an exposure of concern from its misuse. • Some Contingency Plans might be generic across the Schools/Institutes etc. as the same 'types' of operations are carried out but in different places. Because of this, some example Contingency Plans for typical radiation accidents in Sealed Sources work are included on the RPU website: ○ https://www.ed.ac.uk/health-safety/radiation-protection/radiation-protection-management • The example contingency plans are not intended for direct implementation into departmental Local Rules as some details need to be added to make them applicable to each area.
• Consideration must be given to accident scenarios that could lead to offsite emergencies.	• A Radiation Risk Assessment (RRA) has been carried out by the University RPU against the requirements of the Radiation (Emergency Preparedness and Public Information) Regulations 2019 "REPPIR". This Risk Assessment is managed centrally by the RPU and available on request. • The assessment concluded that the quantity and type of sources held by the University would not lead to an effective dose greater than 1mSv to a member of the public following a radiation emergency.

What the HSE expects	Further Guidance
• If circumstances arise where it is necessary for all, or part of, arrangements in a contingency plan to be used then a report must be written and kept for two years.	• As a report is required to be written and kept, the University RPA must be informed of any radiation accidents where all, or part of, a contingency plan is enacted. • Contacting the University RPA should therefore feature in all Contingency Plans so they can advise on the content of any report. Although the report does not need to be sent to the HSE, the HSE can ask to see it, or be sent it, if they request to do so. • Note, other incidents which occur but which do not involve a Contingency Plan may require an incident report to be written; for example through the University's Accident and Incident Reporting (AIR) system.
• Where appropriate, rehearsals of the arrangements within Contingency Plans must be carried out at suitable intervals.	• Where appropriate, rehearsals of the arrangements in Contingency Plans must be carried out at suitable intervals. Desktop rehearsals may be appropriate in cases where contingency arrangements are simple and doses from reasonably foreseeable accidents are low. • RPSs should arrange for Contingency Plan rehearsals to take place as part of their local training. • Records of rehearsals (e.g. what parts of the Contingency Plans were tested, who attended and on what date) must be kept in case they are required during an audit or inspection.

5.9 (i) The training needs of classified and non-classified employees

What the HSE expects	Further Guidance
• Employers engaged in work with ionising radiation need to demonstrate that their employees have been given sufficient information, instruction and training.	• All workers who wish to work unsupervised with ionising radiation must be given appropriate information, instruction and training to ensure that they know; ○ The risks to their health from exposure to ionising radiation (*i.e. having the background knowledge in ionising radiation*); ○ The precautions that need to be taken to ensure their radiation exposures are managed As Low As is Reasonably Practicable (ALARP) when working with Sealed Sources (*i.e. local instruction or induction from the RPS or manufacturer's training on the equipment*); and

What the HSE expects	Further Guidance
	○ The importance of complying with the regulations (*i.e. having the appropriate legislative knowledge from IRR17 on what arrangements are in place to comply with the law*). • The above instruction and training requirements are normally met by: ○ Attending one of the University's Basic Courses in Radiation Protection (e.g. The Basic Course Research & Teaching or the Basic Course in Veterinary Diagnostic Imaging & Therapy); and, ○ Completing and passing the relevant competence assessment(s) on LEARN, the University's Virtual Learning Environment, linked to the training course modules being sat; and, ○ Receiving practical instruction from the RPS or Deputy RPS on the *local arrangements* within the area for working with ionising radiation. • Line managers and academic supervisors should ensure that arrangements are made for staff to receive the appropriate training. This can be done in conjunction with the RPS. • Further guidance on training can be found in Radiation Protection Code of Practice RP CoP008 "*Information, Instruction & Training in work with radiation sources*".
• Adequate information is given to other persons who may be involved in the work with ionising radiation either directly or indirectly.	• Other persons may need to be given information or instruction or training to ensure they can work safely and reduce risks to their health. Other persons that may need information, instruction or training might be: • Domestic (cleaning) staff: ○ Access arrangements; ○ What can and cannot be cleaned; ○ What can and cannot be taken out of the area (e.g. emptying of bins); ○ Basic principles of time, distance and shielding to reduce external radiation hazard; • Service/maintenance engineers; ○ Service or maintenance engineers may need to be given information or instruction, particularly if they are entering a Controlled or Supervised Area;

What the HSE expects	Further Guidance
	◦ Normally, service engineers take control of the area, and therefore are responsible for managing their own risks. A 'handover' form is provided on the RPU website and should be included in the Local Rules for the area to cover any equipment being serviced, see: ▪ https://www.ed.ac.uk/health-safety/radiation-protection/radiation-protection-management • Other persons in the building (e.g. other research staff or office staff); ◦ Other workers who may work in the vicinity of a HASS; ◦ These workers should receive some instruction on the hazards in the area and any actions they are required to take; particularly in an accident situation; • Visitors may not need any formal training provided they are closely supervised when in a Controlled or Supervised Area and do not work with the sealed sources;
• Training records to be kept	• All training, and even local instruction, must be recorded and those records maintained. • Line managers and academic supervisors should notify the RPS when refresher training is required.
• Persons working with ionising radiation must repeat their training at regular intervals	• In order to maintain the competence levels of staff and other persons working with ionising radiation, refresher training must be scheduled at regular intervals; • There is no definite time interval for refresher training but the RPU advise that the interval between refresher training should not normally exceed 5 years.

5.10 (j) The need to designate specific areas as Controlled or Supervised areas and to specify local rules

What the HSE expects	Further Guidance

• Areas to be designated as Controlled or Supervised areas if there is a need to control who can enter or work in the area to reduce radiation exposures.	• If there is a need to control who can enter or work in an area, to reduce their potential radiation exposure, then it is likely to be necessary to designate a Controlled or Supervised Area. The purpose of designated areas is to manage radiation risk by separating higher risk activities from lower risk activities.
	• Risk assessors must consider not only workers but other persons who may need to work in the area, for example other students or persons who are not trained or connected with the work.
	• The decision on whether to designate an area should consider any reasonably foreseeable accident and incidents, including the failure of protection measures.
	• Additional guidance on the designation of Controlled and Supervised Areas, including a step-by-step guide on how to determine the area designation, can be found in RP CoP011 "*Controlled and Supervised Areas*".
	• Most gamma irradiators contain sufficient engineering controls such that elevated dose rates are not normally expected; therefore they may not require designation as a Controlled or Supervised Area.
	    ○ Access to the room would still require to be controlled (for security purposes) and Local Rules would normally still be appropriate.
	CONTROLLED AREAS:
	• Controlled areas are designated when it is necessary for persons to follow *special procedures designed to restrict significant exposures* in the area. For example, Controlled Areas must be designated where:
	    ○ The *accessible* external dose rate in the area exceeds 7.5 μSv/h when averaged over the working day (8 hours);
	    ○ A person's hands can enter an area where the dose rate exceeds 75 μSv/h when averaged over the working day (8 hours);
	    ○ Access restriction to the area by people unconnected with the work is required to restrict any foreseeable and significant doses that they might receive;

What the HSE expects	Further Guidance
	○ Effective whole-body doses received by persons working in the area could exceed 6 mSv/y or equivalent doses could exceed 15 mSv/y to the lens of the eye or 150 mSv/y to the extremities. • Examples where designation of a Controlled Area would be appropriate for sealed source work would include: ○ Radiation stores/rooms used for the storage of sealed sources where the dose rate exceeds 7.5 µSv/h (if a person can enter the store) or 75 µSv/h (if only the hands can enter the store). **SUPERVISED AREAS:** • Supervised areas are designated where the risk of exposure is lower but where working conditions are still required to be kept under review in case things change. ○ Supervised areas should be designated where whole-body effective doses received by persons working in the area could exceed 1mSv/y or equivalent doses could exceed 5 mSv/y to the lens of the eye or 50 mSv/y to the extremities. • Examples where designation of a Supervised Area would be appropriate for sealed source work would include: ○ A teaching laboratory where sealed sources are temporarily removed from storage for use in an experiment or experiments during which they are subject to constant supervision; ○ Radiation stores/rooms used for the storage of sealed sources where the dose rate exceeds 2.5 µSv/h (if a person can enter the store);
• Adequate demarcation of the designated area must be provided.	• Once the designated area has been established, it needs to be demarcated and segregated from areas which are not designated to restrict unauthorised access. • For Controlled Areas, it is advised to use physical boundaries, such as walls and doors, to signify the extent of the Controlled Area; a line across the floor is not normally sufficient. • For Supervised Areas, a physical boundary is not always required but it must still be demarcated. • Whatever demarcation is chosen, refer to it in the local rules (e.g. a picture or drawing of the area).

What the HSE expects	Further Guidance
• Persons must be warned of the presence of the designated area.	• If an area is designated as a Controlled or Supervised area then it needs to be accompanied by a sign, **at the entrance to the designated area**, informing persons of the hazard within the area. ○ In most cases this will be the door to the lab/room **but not always!** • This demarcation is done via Controlled or Supervised area notices. Examples of these notices can be found at the back of RP CoP011. • Copies of the signs can be downloaded from the RPU website at the link below. It is important that signs across the University are consistent; **do not use your own version!** • Controlled Area notices must have a yellow background and Supervised Areas a white background. • https://www.ed.ac.uk/health-safety/radiation-protection/radiation-protection-management/signs

• Local Rules are required for all Controlled areas and some Supervised Areas taking into account the work being carried out.	• In most cases, work with Sealed Sources should be accompanied by Local Rules to ensure procedures are followed to reduce the likelihood of significant exposures.
	• Local Rules for work with Sealed Sources must contain:
	  ○ The Dose Investigation Level (DIL) set in 5.6 (f) above;
	  ○ A summary of the contingency arrangements set out in 5.8 (h) above;
	  ○ The name of the appointed Radiation Protection Supervisor;
	  ○ A description and identification of the area covered by the Local Rules;
	  ○ A summary of the key working instructions for restricting access to the area;
	  ○ The written arrangements for non-classified workers (i.e. the steps they need to follow to keep their radiation exposures as low as reasonably practicable when in the area).
	• It is also advised that the Local Rules also provide information on the following:
	  ○ A summary of the arrangements for pregnant and breast-feeding staff set out in 5.5 (e);
	  ○ A link to the Risk Assessment carried out for the work;

What the HSE expects	Further Guidance
	○ Arrangements for the information, instruction and training of staff and other persons who wish to work in the area or who are affected by the work in the area (as set out in 5.9 (i)); ○ Personal dosimetry arrangements as set out in 5.13 (m); ○ Arrangements for any PPE required for the area as set out in 5.3 (c); ○ Arrangements for radiation monitoring of the area to ensure that the area is designated correctly or to confirm it doesn't require designation (see RP CoP003); ○ Arrangements for managing service engineers and others who may need to enter the area to carry out work; • The University RPU have created model local rules for sealed sources work to capture many of the routine procedural controls designed to reduce exposures to ionising radiation. These model local rules can be found here: ○ https://www.ed.ac.uk/health-safety/radiation-protection/radiation-protection-management/local-rules
• The appointment of an RPS to supervise the arrangements set out in the Local Rules.	• In almost all cases, a Radiation Protection Supervisor (RPS) will need to be appointed to oversee the arrangements set out in the Local Rules; i.e. an RPS is almost always required where there is work with sealed sources. • As mentioned above, the RPS must be named, along with their contact details, in the Local Rules for the area. • Further information on the typical duties that an RPS may carry out are given in RP CoP001 "*Radiation Protection Supervisors*": ○ https://www.ed.ac.uk/health-safety/radiation-protection/codes-of-practice-and-guidance/codes-of-practice

5.11 (k) The actions needed to make sure access is restricted and other specific measures are put in place in Controlled or Supervised areas

What the HSE expects	Further Guidance
• Employers who have designated a Controlled Area must not permit any person to enter or remain in that area unless they meet various criteria.	• Consider in your Risk Assessment who needs to access the area where you are working and how they, and others, might access the area. ○ Is the building open access to members of the public and visitors? (i.e. can anyone walk in?) ○ Is there a swipe card entry system to the building/floor/laboratory? Who manages access requests for that system and how are persons granted access to laboratory spaces or rooms where work with sealed sources is taking place? ○ Is there a key-code or PIN to enter the laboratory or room? If so, when was the code last changed? Is there a process to record this change and frequency? • Consider how access is to be managed such that only fully trained and authorised persons are able to enter and work in the area. ○ How do you ensure persons working in the area have had the necessary training? ○ How do you ensure they have had local information and instruction to allow them to work safely? ○ How do you ensure they have read the Local Rules? • For Supervised Areas, access must still be managed (e.g. by signage) but access restrictions are not as stringent as those for Controlled Areas.
• It is the responsibility of the employer in control of the area to restrict access.	• In some cases, service engineer's visit premises to carry out "work" in a Controlled or Supervised Area. "Work" could include such things as installation, routine service/repair, adjustment, part replacement, software upgrades, hardware upgrades, reactive visits, etc. • Whenever ionising radiation equipment, e.g. an Irradiator, is handed over to a service engineer or other person, then they must take ownership of the Controlled or Supervised Area and therefore work under their own company's Local Rules and procedures.

What the HSE expects	Further Guidance

• Consider the arrangements for the different types of person who may access the area.	• Most of the University's workers working with Sealed Sources will be non-classified workers entering and working in the area under *written arrangements*.
	  ○ These *written arrangements* must be included in the Local Rules and outline the steps that the non-classified person must take to restrict their exposure.
	  ○ Things to consider include their supervision in the area, what PPE is required to be used (if any) and restrictions on the type of work they are allowed to carry out.
	  ○ Consider other persons who may access the area too (e.g. cleaners, estates personnel, etc)
	• If *Classified Person*s [see 5.12 (I)] need to enter the area:
	  ○ How will you check their medical surveillance is up to date?
	  ○ How will you ensure they are subject to personal dose monitoring?
	• If *Classified outside workers* need to enter the area: (i.e. Classified Persons who have NOT been classified by the University of Edinburgh; e.g. other employers Classified Persons):
	  ○ How will you check their radiation passbook is up to date?
	  ○ How will you ensure they have received the necessary training to enter and work in the area?
	  ○ How will you check that they have been passed fit-to-work by an appointed doctor?
	  ○ How will you ensure that they are subject to routine dose assessment by an Approved Dosimetry Service?
	• Non-classified outside workers are persons, who are not classified persons, but who carry out 'services' in a Controlled or Supervised area which has not been designated by their own employer. For example, a service engineer coming to fix a piece of equipment where the background dose rate in the area exceeds 7.5 microSv/h.
	  ○ Access arrangements for these types of workers should be included in the written arrangements if they are required.

5.12 (l) The need to designate certain employees as Classified Persons

What the HSE expects	Further Guidance
• Employers must designate employees who are *likely* to receive an effective dose greater than 6mSv in a year or an equivalent dose greater than 15mSv to the lens of the eye or 150mSv to the skin or extremities. • The employer should take into account not only routine work but the possibility of accidents *likely* to occur.	• Under normal circumstances, *routine* work with Sealed Sources is unlikely to result in effective doses in excess of 6mSv or equivalent doses in excess of those mentioned in Column 1. • However, the IRR17 require employers to also consider classifying persons on the basis of *potential* exposure from any reasonably foreseeable radiation accident. • Even in reasonably foreseeable accident situations, it is unlikely that persons working with sealed sources at the University could receive doses in excess of those in Column 1. ○ **The University therefore doesn't expect to have to designate Classified Persons for the majority of its work with Sealed Sources.** • Further information on Classified Persons can be found in Radiation Protection Code of Practice RP CoP_015 *"Classified Radiation Workers*". ○ https://www.ed.ac.uk/health-safety/radiation-protection/codes-of-practice-and-guidance/codes-of-practice

5.13 (m) The content of a suitable programme of dose assessment for employees designated as Classified Persons and for others who enter Controlled Areas

What the HSE expects	Further Guidance
• Dose assessment for Classified Persons	• Classified Persons are not expected to be required for work with Sealed Sources. However, guidance on a suitable programme for dose assessment for Classified Persons is given in Radiation Protection Code of Practice RP CoP015 "*Classified Radiation Workers*".

What the HSE expects	Further Guidance

• Dose assessment for non-classified persons	• In most cases, work at the University of Edinburgh with Sealed Sources shouldn't require persons to be designated as Classified Persons however, employers must put arrangements in place to demonstrate that any exposures received will not exceed the relevant dose levels.
	• An employer who decides to make arrangements *other than personal dosimetry* for assessing doses to non-classified persons must be able to demonstrate that the measurements and assessments have been made to a satisfactory standard.
	• Therefore, if workers **ARE NOT** provided with personal dosemeters for assessing the doses from their work, which is often the case for sealed source usage, then the method used to demonstrate that dose limits are not being exceeded must be written down; for example, recorded in the risk assessment.
	    ○ For showing no internal dose can occur when working with Sealed Sources it is sufficient to record that leak testing is being carried out and that, if leak test records are up to date, contamination cannot arise and therefore internal doses are not expected.
	    ○ A measurement of the external dose rate at various distances from the Sealed Source(s) used, combined with the likely handling time per year, could give a reasonable estimate of the likely effective dose received for comparison with the dose investigation level. '*The Radionuclide and Radiation Protection Handbook 2002*' is a useful tool for this and a copy of the Handbook can be downloaded for those in academia at the link here:
	    https://academic.oup.com/rpd/article/98/1/1/1679556
	    ○ A persons hands shouldn't need to be closer than 10cm to an unshielded source (extremity).
	    ○ Sealed Sources being manipulated on a benchtop, or held at 'arm's length', are assumed to be approx. 30cm and 50cm from the torso respectively (i.e. from the 'whole body').
	    ○ It is difficult to envisage a scenario where a person would spend more than 100 hours per calendar year being in close proximity to a source (e.g. for handling).
	    ○ Dose rate monitoring equipment used for this purpose must be subject to an annual periodic test to ensure that any measurements made remain suitable.

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If personal dose monitoring hasn’t been done for a while, or isn’t currently being done, another way to demonstrate compliance with the dose investigation level is to carry out personal dose monitoring for a temporary period; for example 6 months.

If this is done, it is advised that an Approved Dosimetry Service is used to supply the dosemeters and the results recorded as part of the risk assessment.
If personal dosemeters are used, the RPS and RPU must receive a copy of the results.

Dose assessment by the use of personal dosemeters MUST always be carried out where persons work with Sealed Sources or equipment containing Sealed Sources and accessible whole-body dose rates in excess of 7.5 μSv/h are possible.
If situations arise where a person’s hands may be closer than 10cm to unshielded Sealed Sources (i.e. when sources are outside of their immediate container), and there could be a potentially significant extremity dose to the hands/skin, then extremity monitoring may need to be carried out to demonstrate equivalent dose limits and dose investigation levels are not being exceeded.

If this is done, it is advised that an Approved Dosimetry Service is used to supply the dosemeters and the results recorded as part of the risk assessment.
If personal dosemeters are used, the RPS and RPU must receive a copy of the results.
Extremity dosemeters may need to be worn on one or more hands depending on the task. This should be considered as part of the risk assessment.

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Other persons who may enter Controlled Areas
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The written arrangements to allow non-classified persons entry to Controlled Areas also applies to visitors and other persons who may enter the area; for example untrained persons.
The IRR17 state that the employer must demonstrate, by personal dose monitoring or other suitable measurements, that dose limits are not being exceeded for those categories of person.
For work with Sealed Sources, risk assessors could reasonably assume that visitors and other persons would not be handling/working with any Sealed Sources but could approach the outside of a source store.

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What the HSE expects	Further Guidance
	• A measurement of the dose rate from outside the source store combined with a likely 'X hours' of time spent next to the store per calendar year should be sufficient to demonstrate doses will not exceed a Dose Investigation Level for any persons approaching the store. ○ It is difficult to envisage a scenario where a person, who is **not** a worker, would spend more than 50 hours per calendar year in close proximity to a source store. • No extremity dose monitoring is expected to be needed for visitors and other persons as they are unlikely to be handling/working with any Sealed Sources. • No dose monitoring is required to demonstrate that internal doses are not being received by visitors. If workers are not receiving internal doses then it can be assumed that visitors and other persons are not receiving internal doses either.

5.14 (n) The requirements for the leak testing of radioactive sources

What the HSE expects	Further Guidance
• Employers to carry out leakage tests on all their closed sources to ensure the mechanisms preventing dispersal remain adequate and effective.	• The structure of a sealed source is such that it prevents, under normal conditions of use, any dispersion of radioactive material to the environment. It follows then that there must be some check to ensure that this structure is continuing to function as intended; this check is called a *Leak Test*. • The IRR17 deem that any leak test of a sealed source must be 'suitable' and must be carried out at 'suitable' intervals; the interval between leak tests must not normally exceed 2 years. ○ For sealed sources in generally good condition, and within their recommended working life[2], a leak test every two years is appropriate;

[2] The recommended working life (RWL) of a sealed source is usually provided by the manufacturer or supplier at the point of purchase. If a RWL is not specified by the manufacturer or supplier then a review of the condition of the source, incorporated into the leak test, is recommended to be carried out 5 years post-purchase.

What the HSE expects	Further Guidance
	○ For sealed sources used beyond their recommended working life, for closed sources, or for sources used where there is a greater risk of damage (i.e. high frequency of use) then it is recommended that the leak test period is shorter than 2 years and that the leak test incorporates a '*review*' of the source condition. • The University expects those carrying out leak tests to be trained. As many of the University's sealed sources are greater than 5 years old, and therefore require a review of their condition, the University RPU carries out the leak test on behalf of the source holder. ○ Departments must contact the RPU whenever their leak testing is due to be carried out. ○ A report is issued by the RPU on completion of the leak test. • For the risk assessment, risk assessors should make a note of the leak testing arrangements for their area. A table could be included in the risk assessment which covers: ○ Which sources have been leak tested; ○ When their next scheduled leak test is required. • For HASS, the manufacturer, or their service agent, may carry out the leak test on behalf of the University. Where this is the case, the risk assessment for the HASS should include the arrangements for this. ○ A record of the HASS leak test must be kept.

5.15 (o) The responsibilities of managers and workers (including outside workers) for ensuring compliance with these regulations

What the HSE expects	Further Guidance
• Assigning of responsibilities and duties to ensure compliance with the regulations	• This part of the Risk Assessment is essentially looking for what appointments and arrangements are in place to ensure compliance with the regulations.

<table>
<tr><th>What the HSE expects</th><th>Further Guidance</th></tr>
<tr><td></td><td>

The University has appointed an internal Radiation Protection Adviser (RPA) to provide advice, when consulted, on compliance with the requirements of the Ionising Radiations Regulations 2017 (IRR17); specifically those matters specified in Schedule 4 of the regulations.
Heads of School and other equivalent roles are responsible for the management of health and safety matters within the areas under their control, including ionising radiation.
This responsibility extends to ensuring risk assessments are prepared for all work with ionising radiation although the authority to carry out risk assessments can be delegated to others; such as Principal Investigators, Group Leaders, etc.
Most work with Sealed Sources will require the appointment of a Radiation Protection Supervisor (RPS), by the Head of School or other equivalent role, to supervise the arrangements set out in the Local Rules.
The number of RPSs or assistant/deputy RPSs required to be appointed will depend on the extent of the work undertaken. The Head of School may wish to seek the advice of the University RPA on the appropriate number of RPSs for their areas.
Typical duties of an RPS are outlined in Radiation Protection Code of Practice RP CoP001 “Radiation Protection Supervisors”.
</td></tr>
<tr><td>Responsibilities of workers (including outside workers)</td><td>

All workers, to some extent, have their own responsibilities under health and safety law and there are duties placed on all workers under the Ionising Radiations Regulations.
All persons have to take reasonable care of themselves and others who may be affected by their actions, therefore anyone working with ionising radiation must:

Not knowingly expose themselves, or any other person, to ionising radiation to an extent greater than is reasonably necessary for the purposes of their work (i.e. to work safely);
Correctly use any PPE provided to them, take care of it and store it correctly;
Recognise that they should not continue with a particular task if they feel that they are exposed to a risk to their health and safety that is not being appropriately controlled;

</td></tr>
</table>

What the HSE expects	Further Guidance
	○ Report any accidents, near-misses or other incidents relating to work with ionising radiation; ○ Be aware of the importance of notifying their line manager as soon as possible if they are pregnant or breastfeeding; ○ Attend and complete any training for which they have been nominated/advised to attend; ○ Comply with any local rules, written arrangements or other procedures relating to ionising radiation to which they are working under; ○ Take care of any dosimetry they are provided with and ensure its timely return to allow dose measurements to be made. • Outside workers, i.e. those who carry out 'services' in another employers Controlled Area, may be at particular risk as they may be unfamiliar with the hazards and controls in the other employers Controlled Area; • Consider whether outside workers may enter and work under your risk assessment and what additional measures or controls need to be put in place to ensure they comply with the regulations and Local Rules.

5.16 (p) An appropriate programme of monitoring or auditing of arrangements to check the requirements of these regulations are being met

What the HSE expects	Further Guidance
• Radiation Protection Unit auditing	• The University Radiation Protection Unit undertake a rolling programme of lab/room inspections and audits of departments/schools using Sealed Sources. • In addition, for Sealed Sources classed as High Activity Sealed Sources, an annual visit by the Counter Terrorism Security Adviser is normally carried out which will include some of the requirements laid out in the IRR17 regulations for sealed sources.

What the HSE expects	Further Guidance
	• Audits focus more on the *arrangements* for radiation protection management within the schools whereas lab/room inspections focus on the *actual control measures* implemented down at local level in individual areas. • For Sealed Sources risk assessments, risk assessors should include when the last RPU audit was carried out and also include when the next audit is scheduled for. It may also be worth including any open or incomplete actions from the audit if they relate to this risk assessment. • Further information on RPU auditing and inspection, including the rolling programme dates, can be found on the RPU webpage at: ○ https://www.ed.ac.uk/health-safety/radiation-protection/radiation-protection-management
• Departmental inspections and reviews	• The audits carried out by the RPU include an element of inspection of various areas/labs. • The RPU strongly encourage departments to carry out their own inspections and the RPU inspection templates are available for all Schools and departments to use for their own internal inspections. • If departmental inspections are carried out in the area, list these on the Risk Assessment (i.e. the previous inspection and the next inspection). It may also be worth including any open or incomplete actions from the departmental inspection if they relate to this risk assessment.

6 Summary of actions & recommendations

What the HSE expects	Further Guidance
• N/A	• If there are any recommended actions that were noted during the review of or creation of the Risk Assessment, record them in the summary section along with the person responsible for taking ownership of the action and an expected date of completion.

7 References

[1] Health and Safety Executive, “Work with Ionising Radiation - Ionising Radiations Regulations 2017 and Approved Code of Practice - 2nd Edition,” The Stationary Office (TSO), 2018.

[2] International Atomic Energy Agency, “Dangerous Quantities of Radioactive Material (D-Values),” https://www.iaea.org/publications/7568/dangerous-quantities-of-radioactive-material-d-values, 2006.

[3] British Standard, “BS EN ISO 2919:2014 - Radiological Protection - Sealed Radioactive Sources - General requirements and Classification,” BSI , 2014.

[4] HEALTH AND SAFETY LABORATORY, “Release Fractions for Radioactive Sources in Fires - FS/99/19,” https://www.hse.gov.uk/research/hsl_pdf/2002/fractrad.pdf , July 2000.

[5] Delacroix et al., “Radionuclide and Radiation Protection Data Handbook,” Radiation Protection Dosimetry, ISBN: 1870965876, 2002.

8 Appendix 1: Estimating radiation doses and dose rates to which anyone can be exposed

In order to be suitable and sufficient, the Risk Assessment needs to include ALL the exposure pathways from routine tasks and from reasonably foreseeable accidents. Examples of routine and accident exposure pathways when working with sealed sources are shown below. Note, this list is not intended to be exhaustive, and each individual use at the University will have its own routine and accident situations that require dose estimates to be made:

Possible Routine tasks	**Possible reasonably foreseeable accidents**
• External dose from receipt of sealed source; including the opening of the package, a routine check for contamination/leaking and its transfer to the sealed source store; • External dose from monthly accountancy checks; • External dose from annual physical inventory checks; • External dose to persons working in the vicinity of the sealed source store; including the dose to untrained persons; • External dose to members of the public from the storage, use and movement of the sealed sources (required by IRR 17 Reg 12(3)); • External dose to persons from routine work with the sealed sources taking into account the anticipated use of the source(s) over an annual period; • Potential dose to persons and the environment from the eventual disposal of the sources at the end of their working life; • External dose to persons from leak testing the sources;	• Loss or theft of an IAEA Category 5 Sealed Source • Loss or theft of a HASS source or a source of similar level of potential hazard (*i.e. a source falling into IAEA Categories 1 – 4 but which may not necessarily be defined as a HASS*) • Fire (*either in the immediate area of the source or involving the source*) • Leaking source during normal operation • Radiation alarm sounds *(i.e. radiation alarms in the vicinity of HASS sources)* • Damage to the source or the source enclosure • Breakdown in controls (e.g. persons not following Local Rules)

8.1 Useful data for selected isotopes

The following table gives relevant dose rate and dose information for selected radioisotopes commonly used as Sealed Sources at the University[3]. Data taken from Ref [5] unless otherwise stated. Those carrying out Risk Assessments can use this information, or other information if they wish, to estimate doses and dose rates from routine and reasonably foreseeable accident situations:

Isotope	Physical Half-life	Main Emissions[4]	Part of the body potentially at risk	Range[5] (approx.)		Half Value Layer in lead (HVL)	Tenth Value Layer in lead (TVL)	External dose rate from a point source containing 1MBq (µSv/h)		
				Air (cm)	Plastic (mm)	(mm)	(mm)	@ 10cm[6]	@ 30cm	@ 1m
Carbon-14 (C-14)	5730 y	157 keV; β	Skin	22	0.3	--	--	760	0	0
Sodium-22 (Na-22)	2.6 y	546 keV; β	Skin / lens of eye	200	1.4	--	--	760	100	9
		511 keV (200%); γ 1275 keV; γ	Whole body (all)	--	--	10	37	33	3.6	0.3
Chlorine-36 (Cl-36)	3e5 y	710 keV; β	Skin / lens of eye	260	2.0	--	--	760	108	10
Iron-55 (Fe-55)	2.68 y	6 keV (25%) γ	Skin / lens of eye	<1	<0.1	<1	<1	0	0	0

[3] The list of radionuclides is not intended to be exhaustive. The data is a summary of useful information which may be used as part of the Risk Assessment.

[4] The figures in brackets show the emissions where they differ significantly from 100%. For Beta energies, β_{max} is quoted. Not all emissions have been listed.

[5] The range is the approx. distance travelled in the material by the ***unshielded*** beta particle. Data taken from [2] for plastic. For Glass, the range of the beta particles is approx. half the distance of its range in plastic. For air, a rule of thumb of "*12ft per MeV*" for beta particles has been used taken from "Health Physics and Radiological Health Handbook" 3rd Edition, 1998. Range data for gammas not shown but assume metres.

[6] Values are approximate using rules-of-thumb formula below where β_{max} > approx. 150keV. Likely to be an overestimate for beta energies <<1MeV.

Isotope	Physical Half-life	Main Emissions[4]	Part of the body potentially at risk	Range[5] (approx.)		Half Value Layer in lead (HVL)	Tenth Value Layer in lead (TVL)	External dose rate from a point source containing 1MBq (μSv/h)		
				Air (cm)	Plastic (mm)	(mm)	(mm)	@ 10cm[6]	@ 30cm	@ 1m
Cobalt-57 (Co-57)	271.8 d	122 keV (86%) γ	Whole body / Skin / lens of eye / extremities	--	--	< 1	1	2.2	0.25	0.02
Cobalt-60 (Co-60)	5.27 y	318 keV β	Skin / lens of eye	116	0.7	--	--	760	12.6	1.1
		1173 & 1332 keV γ	Whole body (all)	--	--	16	46	34	3.9	0.3
Nickel-63 (Ni-63)	100 y	66 keV β	Skin	5	0.1	--	--	0	0	0
Germanium-68 (Ge-68) / Ga-68	271 d	511 keV (200%) γ [Ga-68]	Whole body (all)	--	--	6	17	16	1.7	0.2
Kyrpton-85 (Kr-85)	10.7 y	687 keV β	Skin / lens of eye	250	1.9	--	--	760	115	13
Strontium-90 (Sr-90) / Y-90	28.2 y	2.2 MeV β	Skin / lens of eye	850	9.2	--	--	1500	204	23
Technetium-99 (Tc-99)	2.1E5 y	294 keV β	Skin / lens of eye	100	0.6	--	--	760	5.2	0.6
Iodine-129 (I-129)	1.57E7 y	151 keV β	Skin / lens of eye	22	0.3	--	--	760	0	0
		27 – 40 keV γ	Whole body / Skin / lens of eye / extremities	--	--	< 1	< 1	1.7	0.19	0.02
Barium-133 (Ba-133)	10.5 y	356 keV γ (62%)	Whole body (all)	--	--	1	7	9	1	0.1
		Various EC	Skin / lens of eye	75	0.7	--	--	760	2	0.2

Isotope	Physical Half-life	Main Emissions[4]	Part of the body potentially at risk	Range[5] (approx.)		Half Value Layer in lead (HVL)	Tenth Value Layer in lead (TVL)	External dose rate from a point source containing 1MBq (μSv/h)		
				Air (cm)	Plastic (mm)	(mm)	(mm)	@ 10cm[6]	@ 30cm	@ 1m
Caesium-137 (Cs-137)	30.2 y	512 keV β	Skin / lens of eye	200	3.8	--	--	760	213	24
		662 keV γ	Whole body (all)	--	--	8	24	9	1.1	0.11
Promethium-147 (Pm-147)	2.6 y	225 keV β	Skin / lens of eye	80	0.5	--	--	760	0	0
Europium-152 (Eu-152)	13.5 y	Various β	Skin / lens of eye	250	5.2	--	--	760	25	2.8
		344, 1112 & 1408 keV γ	Whole body / Skin / lens of eye / extremities	--	--	10	38	18	2	0.2
Thallium-204 (Tl-204)	3.8 y	763 keV β	Skin / lens of eye	280	2.2	--	--	760	95	10.5
Americium-241 (Am-241)	433 y	59 keV γ	Whole body / Skin / lens of eye / extremities	--	--	< 1	< 1	1.3	0.15	0.01

8.2 Estimating external doses

8.2.1 Using proprietary Software

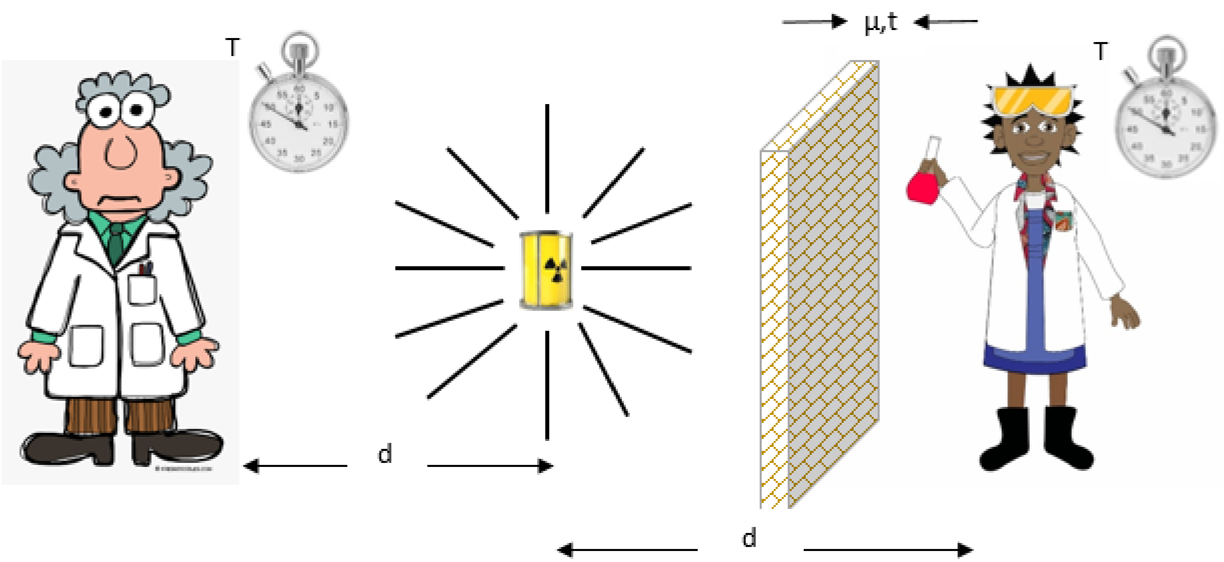
Dose rate and dose calculations can also be made using an on-line software programme - see http://www.radprocalculator.com/default.aspx .

This handy tool provides online calculators for Gamma Activity to dose rate from point sources and beta activity to dose rate from point and plane sources. Shielding can also be added if required however, be warned, the data you get out is only as good as the data you put in.

8.2.2 Using traditional hand calculations

Potential doses can be estimated if there is a knowledge of the:

- dose rates for each type of radiation from the source;
- typical distance of the source from the exposed person(s);
- time of exposure;
- time of emission (i.e. duration of use of the source); and
- any absorbing material in between the source and person.



Without attenuation:

Potential Dose (H) = Dose rate at distance d x Time of exposure (T) x [Time of emission (T)] [1]

Radiation protection is not exact, and doses should be calculated to the nearest part of the body to the source. This dose is normally taken as a "whole-body" dose, for comparison against the dose limits in IRR17. However, it is sometimes necessary to distinguish in between doses to the extremities, skin, eyes and the whole body, and assume distances that are appropriate to these parts of the body. Assume the minimum likely distance to the source when correcting dose rate for distance.

Care should be taken when applying factors for both time of emission ***and*** time of exposure, because there is often a correlation in between the two; for example a source might only be used one hour a day, so the ***USE*** factor is 1/8th of an 8-hour working day (i.e. 12.5%) but the operator will always be there at this time, so the ***OCCUPANCY*** factor in this case would be 1 (i.e. 100%). The following time values are normally used for dose calculations:

Working Period	Assumed Time
Day	8 hours
Week	5 days; 40 hours
Year	50 weeks; 2000 hours

With attenuation:

Potential Dose (H) = Dose rate at distance d x T x attenuation factor [2]

The attenuation of radiation in material depends upon the type of radiation, the energy of the incident radiation, the beam size, and the composition, density and thickness of the material. Where there is already shielding, contact the University RPU for help on estimating attenuation.

Dose Estimate Calculations/methodology:

Radiation Type	*Further information*
Alpha radiation	Due to their high absorption in material, including air and dead skin, exposure to alpha radiation ***externally*** does not result in any dose, and there is no need to calculate dose rates.
Positrons	Because the path of a positron ends up with the production of penetrating gamma radiation, it is often unnecessary to estimate the external dose contribution from the charged particle at distances greater than a few mm (Ref: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4894854/. However, you may need to estimate a skin dose; see below.
Neutrons	Seek advice from the Radiation Protection Unit as estimating neutron doses can be complicated.
Gamma, x- and Beta radiation	In many cases, beta radiation doses may not need to be considered when estimating external doses. There is no need to calculate dose rates from beta radiation at distances greater than the maximum range for that beta energy in air, or other material as appropriate; see 8.1 for beta-range information or 8.3 for guidance on shielding materials. Provided that the dimensions of the source are small, compared to the distance to the observer/person, gamma, x- and beta radiation levels follow the Inverse Square Law (see below).

Distance: The Inverse Square law can be stated as: $DR_2 = (DR_1 \times d_1^2) / d_2^2$ [3]

where DR_1 is the dose rate at distance d_1, and DR_2 is the dose rate at distance d_2.

Using the dose-rate-per-unit-activity at a given distance information in 8.1, the dose rate for any particular activity at points of interest can then be estimated. *Note that this law will not apply at distances close in to the source.* It is usual to express dose rates in dose / hour; for example mSv/h or mSv h^{-1}.

Time:

Dose is linear with exposure time, so: *Dose = Dose rate x exposure (or emission) time* [4]

A time-averaged dose rate, i.e. averaged over an 8-hour period, can be calculated by multiplying the measured dose rate by the fraction of 8h working day when exposure occurs:

Time-averaged dose rate = Instantaneous Dose Rate x Period of Exposure (h) / 8 (h) [5]

Calculation of activity:

The activity of a radioisotope at any particular time can be calculated using the equation: $A_t = A_0 e^{-\lambda t}$ [6]

Where A_0 is the original activity, A_t is the activity after a decay time of t, and λ is the decay constant, which values are readily available on the internet. λ is equal to the 0.693 / half-life.

Calculation of activity (rapidly decaying radionuclides):

The dose arising from short half-life radioisotopes, i.e. those decaying significantly over the period of their use like F-18 or Tc-99m, cannot be accurately estimated from an instantaneous dose rate value. Failing to take decay into account would result in a significant dose overestimate.

The cumulative dose arising from exposure to a rapidly decaying radionuclide can be calculated using the following equation:

$$Dose = \frac{\Gamma\ .\ A_0}{\lambda}\left[e^{-\lambda t_0} - e^{-\lambda t}\right] \quad [7]$$

where Γ is the dose rate / unit activity, A_0 is the initial activity, λ is the decay constant, t_0 is the start of the time period of interest and t is the end of the time period.

If the time period starts at the beginning of exposure, the equation can be reduced to:

$$Dose = \frac{\Gamma\ .\ A_0}{\lambda}\left[1 - e^{-\lambda t}\right] \quad [8]$$

8.2.3 Useful rules of thumb

Estimating dose-rates from penetrating beta emitters:

$$D = 760\ A \qquad [9]$$

Where:

D = the dose rate in $\mu Sv\ h^{-1}$ at a distance of 10cm from a point source.

A = the source activity in MBq.

[Taken from AURPO Guidance Notes on Working with Ionising Radiation in Research and Teaching – March 2019 edition]

Estimating dose-rates from gamma emitters:

$$D = \frac{ME}{6r^2} \qquad [10]$$

Where:

D = dose rate in $\mu Sv\ h^{-1}$

M = the Activity in MBq

E is the energy per disintegration in MeV

r = distance from the source in metres

[Taken from an Introduction to Radiation Protection by Martin and Harbison, page 78]

8.3 Selecting shielding material

The type of shielding required for reducing the dose rate around sealed source receptacles or sealed source stores depends on the type radiation being emitted from the source. Note, many sources will emit more than one type of radiation. The main types of radiation emission are shown below alongside notes and advice on the choice of shielding appropriate to that type of radiation.

Type of radiation emitted by sealed source	Typical shielding material	Notes/comments
Alpha	Paper / source capsule	As alpha particles are very easily shielded, in general, the source capsule prevents the alpha particles from penetrating beyond the boundaries of the source. For homogenous (closed) sources like rocks containing naturally occurring radioactive material, depleted Uranium etc., it is unlikely that alpha particles can escape the surface of the source.
Beta	PMMA / Aluminium	Beta particles are more penetrating than alpha particles and can travel up to several metres in air. Light materials such as PMMA (e.g. Perspex) or Aluminium should be used instead of dense materials like lead or steel as heavier materials produce more Bremsstrahlung[7] radiation. Typically where beta and gamma radiations are emitted, it is common for there to be a light material (e.g. PMMA) followed by a heavy material (e.g. Lead) to provide the required level of shielding. Total absorption of the beta particles depends on the maximum energy of the beta and also the thickness of the absorber material (in mg cm^{-2}). Some example

[7] Bremsstrahlung (literally 'braking radiation') is the electromagnetic radiation resulting from the change in velocity when charged particles are decelerated. The resulting kinetic energy is emitted as a photon. A rough estimate of the fraction, f, of beta energy converted into photons is [$f \approx 3.5 \times 10^{-4} * Z * \beta_{max}$] – where Z is the atomic number of the absorber and β_{max} is in MeV.

Type of radiation emitted by sealed source	Typical shielding material	Notes/comments
		radionuclides predominantly used as Beta sealed sources are shown in 8.1 alongside their maximum range in common absorbers.
Gamma	Lead / Steel / concrete	Gamma radiation, including x-radiation, is the most penetrating form of electromagnetic radiation. Shielding materials for X- and Gamma rays normally consist of heavy materials like lead, steel or concrete. Shielding thicknesses for gamma and x- rays are normally expressed in 'half-value thickness' or 'tenth-value thickness' where the thickness of the shielding material will reduce the radiation intensity to one-half or one-tenth respectively. Some examples of gamma emitting sealed sources and their HVL/TVL thicknesses are shown in 8.1.
Neutron	Water / Boron / Paraffin wax	Neutrons have no net electric charge and therefore cannot be stopped by electric forces. Heavy materials such as lead are ineffective at shielding neutron radiation as it simply passes through the material. The principle of neutron shielding is to first try and slow down the neutrons and then absorb them. Materials with a high hydrogen content are useful at *slowing down* neutrons and materials with a high neutron capture cross section, like Boron, are useful for *capturing* the neutrons. Water can be used for both (if a sufficient thickness is used to capture the neutrons). The act of slowing down the neutrons and capturing them results in additional gamma radiation being emitted; this then requires shielding too. Incorrect placement of the 'gamma' shielding can result in insufficient dose reduction. As the selection of the right shielding material for neutrons can be complex, advice should always be sought from the RPU regarding neutron shielding of sealed sources.