Code of Practice for the Control of Ionising Radiation in the Department of Physics

Scope

This document explains the hazards and the risks associated with the use of radioactive sources and radiation generators. In addition, ALL users need to be aware of the contents of the department rules.

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1. Introduction

Work with ionising radiation is subject to strict control at all workplaces, and the control must be demonstrable to the authorities. All work must comply with the Ionising Radiations Regulations 1999 and, where it is appropriate, the Radioactive Substances Act 1993. Risk assessment is mandatory in all cases, and the objectives of such risk assessments must be to define a system of work that is lawful, that reduces exposure to radiation to the lowest level reasonably practicable, and a workplace that has the necessary level of control and security required by law.

It is not difficult to achieve this level of control, but it is essential that ALL users of ionising radiation AND their supervisors must read and understand the Department Rules and their own Research Group Local Rules. The instructions MUST be carried out by all concerned. The University is at great risk from prosecution or other enforcement action in the area of control of work with ionising radiations if the rules are not followed.

The Department has two Radiation Protection Supervisors who have a Statutory responsibility to ensure that the rules are followed. They also assist in formulating the rules. The names of the Department Radiation Protection Supervisors and their duties are detailed in the Department Rules. In addition we are advised by a Radiation Protection Adviser, who is appointed by the University, and approved by the HSE. The advice of the Radiation Protection Adviser MUST be followed. Appendix A lists the items that require the guidance of the Radiation Protection Adviser. However, a Department Radiation Protection Supervisor should always be consulted in the first instance.

2. Radiation quantities and units

2.1 Activity and Energy

The activity of a radionuclide is the number of nuclear disintegrations per second. The unit is the Becquerel, 1 Bq = 1 disintegration per second.

The energy, measured in electron volts, in general determines the range of the radiation. This is important when deciding on appropriate shielding for a particular experiment.

2.2 Radiation dose - absorbed dose

Radiation dose or absorbed dose is a measure of the energy deposited in a material per unit mass as a result of its interaction with radiation. The unit is the Gray, Gy and 1 Gy = 1 Joule of energy per kilogram of tissue.

2.3 Dose equivalent

The dose equivalent is the absorbed dose modified by a Q factor, to take into account the difference in the biological effects that arise from different types of radiation. This is necessary because some types of radiation are much more destructive than others. The unit of dose equivalent is the Sievert, Sv and Sv = Gy x Q.

Values of Q	
Alpha	20
Neutrons	3 to 10
X, gamma or beta	1

Alpha particles have a very high Q value, which is indicative of the damage that they can do. Note that for X, gamma and beta, because Q is unity, the Gray and Sievert are numerically equal.

For the purposes of radiation protection, the Sievert is the unit that has greatest importance. Therefore, for practical purposes, we need a conversion from the activity of a source to the dose equivalent to personnel.

For beta radiation, there is an empirical formula that can be used:

$$D = 800\ A$$

Where D is the approximate dose rate in $mSvh^{-1}$ at 10 cm from the beta source, and A is its activity in GBq.

Worked example: what is the dose rate at 10 cm from a 3.7 GBq Sr90 source?

$D = 800\ A$
$= 800 \times 3.7\ mSvh^{-1}$
$= 2960\ mSvh^{-1}$
$= 2.96\ Svh^{-1}$

For gamma sources and X-ray generators typical figures are:
Cs-137, 34 $mSvh^{-1}$ at 1 m from a 400 GBq source
Co-60, 138 $mSvh^{-1}$ at 1 m from a 400 GBq source.
50 kV tube voltage, 2 mm Aluminium filtration gives 1.5 Svh^{-1} at 1 m from anode for 10 mA tube current
75 kV tube voltage, identical conditions, gives 3.5 Svh^{-1}

2.4 Old units

Many people are still using old units, and some sources have been in the Cavendish so long that their activities are still recorded in Curie. The table below gives equivalents.

Quantity	Old unit	SI Unit	Conversion
Activity	Curie (Ci)	Becquerel (Bq)	1 Ci = 3.7×10^{10} Bq
Absorbed dose	Rad	Gray (Gy)	1 rad = 0.01 Gy 1 Gy = 100 rad
Dose equivalent	Rem	Sievert (Sv)	1 rem = 0.01 Sv 1 Sv = 100 rem

All risk assessments and source records should be using the SI units, where possible.

2.5 Principles of protection from ionising radiation

There are four factors that affect the dose to personnel: the source activity, time, distance and shielding. The larger the source activity, or the higher the rating of an X-ray set, the greater the potential dose to the individual. Potential doses can therefore be minimised by choosing the smallest activity necessary for the work.

The shorter the time exposed to radiation, the smaller the dose.

When considering the effect of distance, for penetrating radiations such as X and gamma radiation, the dose rate from a point source follows an inverse square relationship. For beta radiation, this is further attenuated by absorption of beta particles by the air.

Alpha radiation is easily shielded by matter - a thin sheet of paper is able to stop the most energetic alpha particles. Beta particles are shielded effectively by light materials, such as perspex or aluminium. Heavier materials such as steel or lead tend to produce Bremstrahlung radiation when they absorb beta particles, and are therefore a poorer choice. X-rays and Gamma rays are best shielded using lead, steel or concrete. For a single radiation energy the attenuation is exponential, and for this reason you can find tables of 'half value' and 'tenth value' thicknesses to assist in planning shielding.

3. Biological Effects

3.1 Introduction

When radiation passes through a biological material, most of the energy deposited (>99%) goes into the production of heat. However the resulting rise in temperature is very small - for example 5 Sv, a dose which would almost certainly be fatal, produces a temperature rise of only approx 1 mK - therefore the exposed person is not going to suffer ill effects from the thermal energy, and will not even feel it.

The remaining 1% of energy is what does the real damage. X and gamma radiation are absorbed by three processes, photoelectric absorption, Compton scattering or pair production. These processes result in the production of energetic electrons which can go on to cause ionisation in the body tissue. Alpha particles and beta particles can cause ionisation directly. Damage to the tissue as a result of ionisation depends on the dose, the dose rate, and the cell type. While a radiation 'burn' is not the same as a thermal burn it may produce similar damage. It is, however, initially painless and the casualty is probably unaware that he or she has been affected. Damage may be felt in the relatively short term (days), or may become apparent in the long term (after tens of years).

Proteins and DNA in the cells are vital to the continued working of those cells, and damage to these molecules can have serious consequences. There are some repair mechanisms, but these cannot cope with all the damage that might occur. Strikes to the DNA may cause the cell to cease to function and die. This will not be too significant provided not too many cells are involved. A single strike on a DNA strand may be repaired if the adjoining strand is intact. Repair may be correct, or the damage may be repaired wrongly. Wrongly repaired DNA could potentially lead to the initiation of a cancer. A double strike to DNA (more likely with neutrons or alpha particles, or very high dose rates of the more penetrating radiations) may cause it to fall apart.

Current experimental evidence indicates that:

1. The cell nucleus is more sensitive to radiation damage than other parts of the cell.
2. Cells are more sensitive to the effects of radiation damage if they are irradiated while undergoing cell division. Hence cells in the gut walls and the blood-forming organs can be at greatest risk. Muscle and nerve tissue show the least radiosensitivity.

3.2 Deterministic Effects

These are the immediate effects of radiation dose. At tens of Sieverts, a cell can be killed immediately or rendered unable to carry out its function. At doses between 0.5 and 10 Sv the cell can no longer divide, but is otherwise unaltered and can still perform its function.

Deterministic effects are expected to occur when a specific threshold dose has been exceeded, above which the severity of the effect is then directly dependent on the dose received. Effects include reddening of the skin, hair loss, nausea, blood count changes. These tend to be acute effects, appearing within days or weeks of exposure. Doses to produce deterministic effects are generally in excess of 0.2 Sv. A skin exposure can lead to death, if a large enough area of the skin is exposed to radiation. The effects of radiation burns are similar to thermal burns.

Radiation sickness is unlikely to appear at a whole body dose of less than around 1 Sv.

It is hard to conceive of any activity in the Department of Physics that could give rise to a large whole-body dose. More localised burns are possible, e.g. as a result of exposure to the primary beam of X-ray apparatus. Look back at section 2.3 for some typical figures.

3.3 Stochastic Effects

Apart from immediate burns and cell death, there are long-term effects of radiation. It is assumed that there is no lower threshold below which these effects will not occur. Disorders such as cancer can be induced. The probability of induction of cancer is proportional to the dose received, but the severity of the effect is independent of dose (in contrast to the deterministic effects).

The probabilities of cancer induction have been derived from studying exposed populations. These are mainly the survivors of the nuclear bombs in 1945, those exposed during the course of their work, such as painters of radium clock dials, and those involved with nuclear arms tests. The International Commission on Radiological Protection (ICRP) estimate the nominal probability coefficient for all radiation induced fatal cancers, averaged over the whole population, to be 5% per Sv. Compare this with the probability that all of us have of developing cancer in our lifetime through causes that are not linked to radiation, which is about 1 in 3.

So far, there is no evidence of hereditary effects in humans, although animal studies suggest that they may be possible.

3.4 Some typical doses

(Source: Background radiation is quoted from local knowledge, remaining figures are from the Health Protection Agency)

Circumstance/effect	Approximate whole body dose
Background (Cambridge area)	2.4 $mSvy^{-1}$
Maximum background in world	50 $mSvy^{-1}$
Average radiation worker	1.5 $mSvy^{-1}$
Annual UK occupational exposure limit (whole body)	20 mSv
Typical single chest X-ray	0.05 mSv
Effects of whole body exposure	
Detectable chromosome damage	> 0.1 Sv
Detectable blood count change	> 1 Sv
Radiation sickness	> 1 Sv
Possible death	> 3 Sv
Certain death	> 10 Sv
Effects of localised exposures	**Localised dose**
Erythema (reddening of the skin)	> 5 Sv
Loss of hair - temporary - permanent	> 4 Sv > 7 Sv
Death of skin/loss of skin	> 20 Sv

3.5 Radiation incidents

There have been a number of incidents associated with direct exposure to radiation, and we need to be aware of the lessons we can learn from them.

One of the most famous is the Goiania incident where a Caesium-137 source was left in an abandoned medical centre and was subsequently 'recovered' by some scrap dealers. This was an unusual source, because it did indeed glow in the dark, and was sold to people as a novelty. Some 249 people were contaminated, and four people died. The root cause of this incident was loss of control of a source when the original owners left it unsupervised.

Another large medical source was taken apart in Mexico, to recover the stainless steel for scrap. Most of the source ended up in a foundry with the steel, and was made into reinforcing bars and table legs. A lorry carrying contaminated table legs became lost in New Mexico and drove past Los Alamos, where it triggered the gamma radiation alarm. This set the investigation in motion. There were fortunately no fatalities, although some people received very large doses. This has the same root cause as the Goiania incident.

An industrial radiographer received a dose of between 20 and 200 Sv to his chest wall from a 25 Ci Iridium-192 source. It was never established how, but it is surmised that he delibberately placed the source in his shirt pocket for a time. A large part of his chest wall, including two ribs had to be removed, and a plate inserted to protect his heart. He was very lucky to survive. (The source activity here has been quoted in Ci, because this incident took place long before SI units were invented).

A research worker forgot to close a manually operated shutter (such a design would no longer be legal), and received a dose to the arm of about 20 Sv. This gave him a skin burn, which healed to a small area of scar tissue in around one month. X-ray sets for crystallography are generally powerful sources of ionising radiation, and exposure to the primary beam can result in dose rates of several Gy per second, which can cause an injury within seconds. The root cause here is human error and demonstrates that reliance on procedure always fails to danger.

An industrial radiographer, who was in the habit of using the interlocking system for turning his X-ray set off at the end of an exposure instead of the 'off' switch on the set, was badly burned when it failed. He received a massive dose to his hand when he was removing the film for processing. Over the course of the following fortnight the burned area became apparent, and the damage was so severe that the tissue in his hand died, and the hand subsequently had to be amputated. The root cause here was failure to use the correct procedure, and over-reliance on the engineering safety measures to compensate for this.

A bald dentist grew a full head of hair after he retired. Throughout his working life, he had unknowingly been 'dosing' himself!

4. Statutory Exposure Limits

It is important to appreciate that the Statutory Exposure Limits do NOT constitute doses that are believed to be safe. No dose is safe, and control must be exerted to reduce the dose to the lowest level reasonably practicable. The acronym for this is ALARP - **as low as is reasonably practicable.**

Dose Limits, per calendar year except where stated.

Region of the body	Employees over 18	Women of reproductive capacity	Others
Whole body	20 mSv		1 mSv
Abdomen		Not greater than 13 mSv in a quarter. Dose to a foetus is not to exceed 1 mSv.	
Lens of eye	150 mSv		
Skin	500 mSv		
Hands, forearms, feet or ankles	500 mSv		

Note the very small dose limit to the foetus. It is known that the embryo and foetus are more sensitive to radiation than either adults or children.

5. Authorisation and Registration of Equipment and Sources

All work with ionising radiation has to be justified on the balance between the expected potential benefits and the potential harm associated with the use. It is anticipated that the classes of work carried out in the University will continue to be regarded as justified.

Work with radioactive substances of significant size has to be approved in advance by the Environment Agency, which issues the University with certificates of registration.

It is important to appreciate that the acquisition of a new source may require the certificate to be changed, and to allow time for this to be done. Please notify the lead Radiation Protection Supervisor, Jane Blunt, if you wish to do this.

The University has generic authorisation from the HSE for its use of radiation generators. This authorisation is subject to certain conditions being fulfilled. In order to ensure that these conditions are met, it is the University policy that all radiation generators are registered on a standard pro-forma registration form. This may be obtained from the Department Lead Radiation Protection Supervisor, or is form IR011 which can be downloaded from http://www.admin.cam.ac.uk/cam-only/offices/safety/radiation/ir/ir011.doc. It must be filled in at an early stage, prior to the completion of the risk assessment and drafting of the local rules. ALL new X-ray equipment MUST be subject to a critical examination at the time of installation, and this must be discussed with the RPS.

6. Risk Assessment and Safe Systems of Work for Ionising Radiation

6.1 Procedure and Dose Constraint

Risk assessment must be carried out prior to commencement of work with Ionising Radiation. It is possible to have a single risk assessment to cover two operations provided they are identical in all significant aspects. It is the responsibility of the users and their research supervisors to identify when a new risk assessment needs to be prepared, or an existing one needs modifying. The Radiation Protection Supervisor, currently Jane Blunt, should be consulted if there is doubt. She is empowered to ask for new or modified assessments to be prepared where she considers this to be necessary.

A copy of the risk assessment should be kept in the work area and should preferably be appended to the experimental protocol or operating procedures. The assessment should be reviewed by the research group annually and if, and when, any significant changes are made to the work. All risk assessments must be approved by a Radiation Protection Supervisor, and this approval formally recorded.

Note that the University has set a dose constraint of 2 mSv, and this requires that at the planning stage of a project, controls must be implemented to restrict the dose to a worker to a ceiling of 2 mSv. However, it is to be noted that our policy is to aim to reduce potential exposure to a level that is as low as reasonably practicable.

6.2 The Five Steps

1. What is the hazard? Clearly, the source of the radiation, or the exposure to it. Also consider things that can go wrong; loss of, damage to, or theft of a source, failure of an interlock, loss of shielding, fire, human error.
2. Who is at risk? How big is the risk? Obviously the worker, but also consider undergraduate students, visitors, cleaning staff, contractors, etc. The public could be at risk from lost or stolen sources. What kind of exposure could there be? Is it entirely external or is there the potential to inhale or ingest a radioactive substance?
3. The risk may be quantified, using the risk factor 5×10^{-2} Sv^{-1} relating to the risk of a fatal cancer as a result of the work. If you do this, then a negligible risk may be taken to be 1 in 10^6 or less, minimal risk is in the range 1 in 10^5 to 1 in 10^6, very low is 1 in 10^4 to 1 in 10^5, and low is 1 in 10^3 to 1 in 10^4. However, numerical risk assessment is not essential.
4. Identification of precautions, and evaluation of the risk remaining: you need to identify the important practical precautions that should be in place to ensure that the risk is low. These then need to be implemented. The assessment of the residual risk also need not be mathematical, but can be expressed in terms of low, medium or high. The aim is to ensure that the residual risk is low and that risks are adequately controlled. Preventive and mitigating measures for reasonably foreseeable accidents and incidents must also be planned.

5. Record the assessment. Use the pro-forma provided, which is form IR008 which can be downloaded from http://www.admin.cam.ac.uk/cam-only/offices/safety/radiation/ir/ir008.doc. There is a worked example in Appendix B
6. Review it at suitable intervals. This is necessary if the situation changes, or if new workers join, or annually by default.

The measures to be taken will include specific training for the users, and should also include recording the routine safety checks, contingency plans, etc.

The risk assessment may define an area of the laboratory to be designated in a special way, such as a controlled area or a supervised area.

6.3 Controlled areas

Controlled areas are those in which it is necessary to follow special procedures designed to restrict significant exposure, taking into account foreseeable accidents. It is not anticipated that this Department will have any such areas. Entry into such areas is restricted by law to 'Classified Workers' (of which the Department has none) or others entering under a written system of work. A typical example of a controlled area is a shielded room within which industrial gamma radiography is carried out. It is not possible to interlock the gamma source itself to the door mechanism, so safety relies to a degree on good working practices.

An area must be designated **Controlled** if a person working in the area is likely to receive a dose in excess of 7.5 μSvh^{-1} or if people working in the area are likely to receive an effective dose in excess of 6 mSv in a year.

6.4 Supervised areas

'Supervised' areas are where working conditions need to be kept under review. It might be appropriate to designate areas within the Department where radiation work is carried out as 'Supervised' areas. If so, then the access points should be demarcated using the trefoil symbol, and the legend 'Supervised area' along with a warning of the hazard (e.g. radioactive material). Working conditions must be kept under review, along with records of workplace monitoring.

6.5 Minimising the risk by engineering controls

In order to minimise the risk of exposure to radiation engineering controls are preferred to any other. For a radiation generator these would include adequate shielding around the radiation source, with access via doors that are interlocked to the power source. For a radioactive material it is more difficult to introduce engineering controls.

Shielding has to be chosen carefully. Alpha particles are the easiest to shield, since it only requires a piece of paper to stop them. Thus alpha emitters are only a problem if they can be inhaled or ingested (an industrial example would be welders who grind thoriated tungsten TIG electrodes, creating dust).

Beta emitters have a range of around 4 m per MeV in air or 3.5 mm per MeV in perspex. Light materials are a better choice for stopping high energy beta particles than heavier materials such as steel or lead. This is because when beta particles are incident on a material such as lead, Bremsstrahlung radiation (X-ray) is liable to be produced.

X-ray and gamma ray sources are usually shielded using lead, steel or concrete. Attenuation follows an exponential law, so that if a 1 cm shield gives a factor 2 reduction, a 2 cm shield gives a factor 4, and a 3 cm shield gives a factor 8. Tables are available to give the attenuation of materials for different energies of radiation.

Most radiation generators are equipped with warning devices, such as lights or sirens, to indicate that the beam is being produced.

Shielding should be designed so that external dose rates are so low that the area around the equipment does not have to be designated 'controlled' or 'supervised'.

6.6 Working practices

It is appropriate for all radiation work to be accompanied by written systems of work, to establish safe working practices.

If there are operations where the danger is increased, such as beam alignment, this work should be restricted to named competent people. It is essential that if any work reduces the safety measures at the engineering control level, a safe system of work at the procedural level is devised to compensate for this. There must be a system for checking that the normal controls have been reinstated before the other radiation workers have access to the equipment.

Such special procedures must be described in the Local Rules.

6.7 Radiation workers

With the exception of persons who will only be using electron microscopes, all persons who work with ionising radiations must be registered, and have training.

A standard proforma downloadable from http://www.admin.cam.ac.uk/cam-only/offices/safety/radiation/ir/ir016.doc (IR016) is used to record their registration. The form should be filled out initially by the prospective worker, to record a simple description of the proposed work and their relevant experience. The research supervisor or line manager should then approve the form. The individual, his/her supervisor and the relevant Radiation Protection Supervisor should then meet to discuss the work and identify any additional practical or training requirements.

The Radiation Protection Supervisor must then make arrangements for the individual to attend any training course that is deemed necessary as soon as possible, together with practical training within the department. The Department retains a copy of the registration form.

When satisfied, the Radiation Protection Supervisor signs the form to give approval and records any conditions, such as dosimetry, preliminary supervision, etc. The applicant signs the required declaration to agree to work safely, and is given a copy of the Department Rules, any local rules relevant to their own work and a copy of 'Working Safely with Sealed Radioactive Sources and Radiation Generators'.

Female workers **must** be informed of the possible risk to the foetus associated with work with ionising radiations during pregnancy. Female workers **must** inform the Department and Personnel Division if they become pregnant or are breast feeding an infant. The advice of the Radiation Protection Adviser must be sought for radiation work to be undertaken during pregnancy or when nursing an infant.

6.8 Work at other sites

When employees of the University visit other sites and undertake radiation work there (such as Isis or CERN), they should endeavour to ensure that the standards of safety are at least as good as those at the University. When working on another's premises they should seek out the host's Radiation Protection Supervisor (or equivalent) and ask to be familiarised with the local rules. Any dosimetry that they are offered should be accepted, and they should ensure that the host has their correct name registered with the badge. They should ensure that arrangements have been made to forward any dosimetry results to the Department Radiation Protection Supervisor.

6.9 Embedded companies

Work done by embedded companies with ionising radiation MUST be discussed with the University Radiation Officer. This work is subject to contractual agreement.

7. Local rules

The Ionising Radiation Regulations require that written local rules are available for all work in controlled areas and, where appropriate, in supervised areas.

Local rules are required to contain the following elements:

- The identification of the area covered by the rules, and whether it is a controlled or supervised area. Any other area is undesignated, where very low risk work takes place, but where there may still ne some practical precautions necessary, such as accounting for sources.
- The organisational arrangements - who is in charge of the work, their name and contact details.
- The name and contact details of the RPSs.
- Who is responsible for the risk assessments.
- The reporting arrangements for accidents and incidents.
- A description of the general and special precautions and contingency plans. These should not be in detail and can refer to other more detailed document(s).
- Essential working instructions and special procedures if any non-classified worker is to enter a controlled area.
- A statement of the University formal dose investigation limit (2mSv).
- Any warning signs required.

Local rules must be brought to the attention of all those who are affected by them.

8. Dosimetry and Monitoring of the Workplace

8.1 Dosimetry

It is University policy that badges are issued to the following people: those working directly with any radiation source capable of delivering a significant exposure. In practice this means those working with radioactive substances.

It should NOT be necessary to issue dosemeters to undergraduates who are undertaking supervised practicals and demonstrations.

Dosemeters are issued by Addenbrookes' Hospital to the Radiation Protection Supervisor for the Department. They are valid for one month, and are due to be replaced on the first day of each month or as soon as possible thereafter. It is essential that users co-operate in the return of badges. It is strongly recommended that each user keep his or her badge in a prominent place (such as propped on top of the electrical conduit), to aid in this process. Late return of dosemeters (i.e. not in the correct month) triggers formal investigation by the University.

Standard dosemeters are for 'whole body' dose, and should be worn on the outside of the clothing at all times when radiation work is being undertaken. Where an operation could expose a part of the body, such as the fingers, to a high dose, there may be a need for a special dosemeter, and this should be discussed with the Radiation Protection Supervisor (and then the Radiation Protection Adviser).

Before a new worker is issued with a badge, he or she must be approved by a Radiation Protection Supervisor and formally registered for the work using form IR016. A request must be made for a badge to the Radiation Protection Supervisor, Jane Blunt, and the badge is likely to be available within around four days.

When a worker no longer needs a badge, he or she should notify Jane Blunt, so that the service can be terminated.

Each month the dosimetry service sends a summary of the badge results to the department where they are reviewed by the Radiation Protection Supervisor. Any reading in excess of 0.3mSv will trigger an internal enquiry to seek an explanation. Any aggregate dose in excess of 2mSv will trigger a formal enquiry from the University.

If a badge is lost or damaged, contact Jane Blunt immediately, to arrange a replacement.

The dose reports, in anonymised form, are reported to the Department Safety Committee each year.

8.2 Monitoring of the Workplace

Monitoring of the workplace is intended to demonstrate that the protective measures are still working, for instance to show that leakage is not occurring. Monitoring of equipment that is equipped with radiation shielding (such as X-ray sets) should be undertaken at least annually, and the results recorded in writing. These written records must be available for inspection by the HSE, and must be retained for at least two years. If you do not record the results in writing, you cannot prove that you have fulfilled this requirement.

When X-ray equipment was installed, it was subject to a critical examination to check that the shielding and all the safety features, such as interlocks and warning lights, were in full working order. If a piece of equipment is moved to a different location, a critical examination must be done again - please contact the RPS to arrange this.

When recording your readings, it is bad practice to record 'zero'. It is better to record them as '< X counts per second' or '< X Sv h^{-1}'.

Monitoring instruments MUST, by law, be calibrated at intervals not exceeding 12 months, and they should also be recalibrated following any repair. Calibration is organised for us by the University, through the lead Radiation Protection Supervisor, and involves half the instruments being removed one week, and the other half the following week. Please assist in this matter by making your instruments available on time. Any instrument that is not calibrated must not be used. We have a small stock of surplus calibrated instruments, which can be used in an emergency. Certificates of calibration are kept by the Lead Radiation Protection Supervisor, for a period of at least two years.

9. Storage, Accounting for, and Disposal of, Sources

9.1 Storage

The storage of radioactive substances is regulated by the Environment Agency. Security of sources, and recorded inspections to ensure that the sources are all still present are of high importance.

A suitable radioactive store will meet the following criteria:

1. The store should be secure and not readily removed.
2. The store should be locked.
3. The keys to the store should only be accessible to those who need to enter the store and are authorised to withdraw radioactive substances.
4. The store should be dedicated to the storage of radioactive substances, wherever reasonably practicable. In any case it should not contain highly flammable, corrosive or explosive materials.
5. The stores should provide adequate shielding so that the external dose rate should not exceed 2.5 μSv h^{-1}.
6. The store should provide suitable environmental conditions for the sources.
7. The store should be protected against fire where damage to the source might result in dispersal of material of dose to an individual.

8. The store should be labelled with the radiation trefoil sign and details of who should be contacted in an emergency.

It is preferred that the store should be in a room without windows, and that the entrances have sturdy, lockable doors.

Containers for radioactive materials should as a minimum be labelled with the trefoil sign and the word 'radioactive'. The labelling must include the unique Departmental identifier and should normally include details of the radionuclide and the nominal activity.

For sealed sources, leak testing is required at least once every two years. Records of these tests must be kept until two years after the source has been disposed of, or until the subsequent test. The Department Lead Radiation Protection Supervisor will keep records of these tests.

9.2 Accounting for Sources

It is absolutely essential that we can account for the location of every single source at all times. This cannot be over-emphasised. Every radioactive source must be assigned to a named member of the Department, who is responsible for its safe keeping. Every radioactive source must be assigned a unique Departmental number, in addition to the manufacturer's serial or batch number. This will assist in accounting for sources.

While only the large sources are individually registered with the Environment Agency, there are limits on the aggregate quantities of many other sources that we are allowed to keep. In addition, although some of our sources are exempt, their status is constantly under review. We therefore must keep an accurate record of all our sources, and for this reason, the list should be reviewed at least annually.

The lead Radiation Protection Supervisor for the Department will collate the records of sources.

9.3 Disposal of Radioactive Sources

The disposal of radioactive substances is regulated by the Environment Agency. Radioactive substances must normally be disposed of through a specialist contractor. It is essential that anyone who wishes to dispose of a source contacts the Department lead Radiation Protection Supervisor. Arrangements will then be made through the University Safety Office. This applies whether the source was individually licensed or not.

10. Contingencies & Reporting of Incidents

10.1 Contingencies

In the event of any incident, accident, fault or suspected fault of a radiation generator, the electricity supply must be switched off immediately and the Radiation Protection Supervisor informed. If the matter is an incident which has, or could have, resulted in failure of safety devices or exposure of persons to ionising radiation then the Safety Office must also be informed immediately.

In the event of an incident with a sealed source it must, if reasonably practicable, be returned to its safe condition as soon as possible. Failure of a radioactive source to return to a safe condition (e.g. the failure of a winding out mechanism from a sealed pot) is itself a matter reportable to the HSE, so it is important to inform the Radiation Protection Supervisor and the Safety Office as quickly as possible.

In the event of fire in the buildings, it is important to notify the Radiation Protection Supervisor if a radioactive store has been threatened. Plans will need to be drawn up for the isolation of the danger area, so that no-one may enter and receive a dose. Safe recovery can then be planned, in conjunction with the Radiation Protection Adviser. NO-ONE has the authority to approach such a task except under a written system of work, founded on a suitable risk assessment.

If it is believed that any person has been exposed to ionising radiation, it is essential to inform the Radiation Protection Supervisor as soon as possible. It will be necessary to make an estimate of the dose, and arrange for whatever follow-up of the casualty is appropriate in the circumstances. Serious cases will warrant investigation by the Safety Office, and possibly the HSE.

If it is believed that the radiation dosemeter belonging to an individual has been damaged, or has been exposed to radiation (while not on the person!) then it is important to contact the Radiation Protection Supervisor, who will arrange for a replacement badge to be issued. Ignoring such an event is likely to lead to a great deal of grief if the first sign of trouble is a high badge reading in the monthly records. There is, in general, a requirement for formal investigation of high doses. In the event that it is known that the badge has been exposed while its owner has not, and we can give a numerical estimate of dose which is close to the dose actually measured, then the matter is relatively easily closed. If not, we can have a difficult time!

10.2 Incidents that must be reported

The following must be reported immediately to the Department Radiation Protection Supervisor:

1. Loss of, damage to, or accidental exposure of a radiation badge.
2. Missing radioactive sources, and any case where there are grounds for suspecting that they have been mislaid.
3. Break-ins, where there is a likelihood that radioactive sources have been disturbed or removed from the premises.
4. Fires, floods or structural collapse that involved or might have involved radioactive sources or radioactive wastes.
5. Any radiation injury, e.g. an X-ray burn, or any injury that could be contaminated by radioactive material.
6. Any possibly significant exposure to external radiation, including any exposure to the primary beam emitted by an X-ray source.
7. Any doses in excess of the University's formal investigation levels (the Radiation Protection Supervisor will be monitoring records for this directly).
8. Any failure of the means used to terminate the exposure from an X-ray source.
9. Any failure of an interlock used to prevent exposure to an X-ray source.
10. Any failure of an interlock or exposure/source transport mechanism used in connection with a high activity gamma radiation source.
11. Physical damage to any sealed radioactive source.
12. Suspected intakes of radionuclides.
13. Any bodily contamination of a person, e.g. skin, eyes.
14. Contamination of a person's clothing, other than disposable gloves.
15. Any spill requiring a laboratory, other area or part of such to be closed pending decontamination.
16. Contamination detected in unexpected areas, i.e. other than on benches and sinks (e.g. walls or floors)
17. Contamination detected outside of a designated controlled or supervised area.
18. Any unexpected delivery of radioactive sources to a department
19. Loss from, or any suspected interference with a radioactive waste store.

11. Transport of Radioactive Substances

Collection of waste and movement to the store at High Cross is managed by the University Radiation Officer, and carried out by a specially trained driver.

Transport of radioactive substances is subject to the Radioactive Materials (Road Transport) Regulations 2002. In order to ensure that we are taking the right steps, anyone wishing to transport a radioactive substance off the site must consult the University Radiation Officer to ensure that the correct procedures are followed.

Appendix A: Matters that Require Consultation with the Radiation Protection Adviser (RPA)

(Matters relevant only to medical uses or uses of unsealed sources have been omitted).

Aspect of the work	**Comments**
Prior examination of plans for new installations and physical control measures	▪ Design of radiochemical laboratories ▪ Any new or significantly modified equipment utilising a radiation generator (including X-ray) Installed equipment incorporating sealed sources if it incorporates shielding, interlocks, shutters, etc
Risk assessments	All new risk assessments unless they fall within existing models approved by the RPA, and only then if all the listed precautions in an existing assessment will be applied.
Contingency plans	▪ Contingency plans for any controlled area ▪ Any contingency plan that requires special measures such as evacuation of a building.
Critical examinations by those installing equipment producing ionising radiations	This should be addressed during the discussions carried out at the planning stage. The installer may have their own RPA, but the University RPA must be consulted about the critical examination.
Periodic examination and testing of physical control measures and checking of systems of work.	▪ At the planning stage for a new installation. ▪ All written procedures for controlled areas ▪ Any permit to work type documents used for safety critical operations.
Decisions on designation of Controlled and Supervised areas	▪ Any approaches differing from the guidance in this and subsidiary documents. ▪ All new controlled and supervised areas (including transient /short term designation.) ▪ Any designation of areas outside of University premises. ▪ Any new radiation generator (even if to confirm that no designation is necessary)
Specification and application of protection measures for Controlled and Supervised areas.	Any approaches differing from or not covered in the guidance in this document and *Working Safely with Unsealed Radioactive Sources* and *Working Safely with Sealed Radioactive Sources and Radiation Generators.*
Decisions on personal dosimetry	▪ Work where extremity dosemeters are appropriate (see subsidiary guidance) ▪ Any special investigations (e.g. after accidents) ▪ Any proposals to assess intakes of radionuclides.
Periodic testing of radiation monitoring instruments	The Safety Office consults the University RPA on the choice of test supplier. The RPA should be consulted about the use of any equipment not described in the University-wide guidance.
Dose investigations, suspected over-exposures, lost or damaged sources, significant spills and any contamination of persons.	In most situations the Department will first notify the Safety Office who will ensure that the RPA is involved.

Appendix B Worked example of a Risk Assessment

Department of Physics

Risk Assessment Form for Use of Radiation Generators or Radioactive Sources

Location of Work	**Room 194**
Description of Work	*Undergraduate experiment using a Cs-137 source*
Planned start date	*Ongoing*
Source of ionising radiation. Specify:Maximum energy, activity, radionuclide etc.	*Cs 137, 3.7 MBq* *Emits gamma radiation, 0.66 MeV.*
Employees involved	*Heads of Class, Classes technicians*
Others involved	*Postgraduate demonstrators, undergraduate students.*
Any pregnant or breastfeeding persons involved?	*Possible*
Nature of risk	*External radiation hazard (gamma)*
Possible accident situations	*Fire, unauthorised removal of source.*
Estimated dose/dose-rates to persons	*400 GBq gives 34 mSv h^{-1} at 1 m. Thus estimates for this source are: 0.314 μ Sv h^{-1} at 1 m, 1.26 μSv h^{-1} at 0.5 m, or 3140 μSv h^{-1} at 1 cm.*
Possibility of contamination and estimated levels	*None, this is a sealed source.*
Results of previous dosimetry/monitoring in this or similar situations.	*Measured dose rate, using calibrated Geiger counter, at hand position when placing the lead sheets: (this is to be measured)*
Advice about equipment use and maintenance	*Not applicable*
Engineering controls and design features in place or planned	*Source is mounted with a lead backing, locked into the experimental table. Additional lead is placed around. Emission is through a small hole.*
Planned system of work	*Students do not handle the equipment. Demonstrator inserts lead shielding.*
Personal protective equipment provided	*Demonstrator wears latex gloves, for handling the lead shielding (due to its toxicity)*
Any restrictions on access	*Undergraduates, those in charge of classes, members of staff of the laboratory and accompanied visitors only.*
Estimated maximum annual dose to employees and others	*Worst case: the technician who sets up the experiment, and measures the background. Assuming ten minutes setting-up time at 1 cm: 523 μSv to hands, or 0.21 μSv at 0.5 m (whole body).*
Estimated annual risk to employees and others (use 5 x 10^{-2} Sv^{-1})	*1 in 100 million from whole body exposure - negligible. Worst case dose to hands is 1/1000 of relevant dose limit.*

Actions required to achieve radiation exposure that is **A**s **L**ow **A**s is **R**easonably **P**racticable.

Dose constraints for planning	*2 mSv (for a worker) per year.*
Additional controls, design features and testing regimes	*Area should be marked with signs indicating restrictions on access.*
Additional systems of work	
Additional personal protective equipment	
Estimated dose to employee with additional controls in place	
Re-calculated annual risk	
Estimated maximum dose to others with additional controls in place	
Estimated annual risk	*Negligible*
Designation of controlled and supervised areas and limitations on access	*Immediate area to be designated supervised.*
Local rules and radiation protection supervisor	*Local rules to be written and incorporated into class instructions. RPS is Jane Blunt.*
Personal monitoring and need for classification	*Class technician wears radiation badge to record whole-body doses, while setting up and putting away sources.*
How compliance is to be achieved	*Experiment supervised by Heads of Class/demonstrators.*
Dose investigation level	*2 mSv (triggers University level investigation), 0.3 mSv (triggers department investigation).*
Training requirements	*Students to have verbal and written instruction.*
Altered working for pregnant or breastfeeding staff	*None required*
Likelihood of an accident	*Biggest risk is theft of source. Fire is also a possibility*
Consequence of an accident, maximum dose estimate and disruption	*Dose to thief: could be large, if it is placed in a pocket. Disruption, adverse publicity, prosecution. Fire could damage shielding.*
Steps to prevent an accident	*Heads of class, technicians and demonstrators to be made aware of the importance of security. Fire detection is automatic.*
Steps to limit the consequence of an accident.	*After fire, contact Jane Blunt to plan recovery of sources.*

Assessment prepared by ……………………………….

Date: ……………………….. Review date: …………………….

Signed: ……………………… Position: …………………………..

April 2002