Safety Department
Imperial College London
South Kensington Campus
London SW7 2AZ
Tel: +44 (0) 020 7594 9423
safetydept@imperial.ac.uk
www.imperial.ac.uk

Ionising Radiations
Code of Practice and Guidance
Radiation Shielding

Imperial College London shall comply with the Ionising Radiations Regulations 1999, the Environmental Permitting Regulations 2010, and other appropriate legislation ensuring safe, compliant and secure use of sources of ionising radiations.

It is a statutory requirement and College Policy that all exposures to ionising radiations will be kept as low as reasonably practicable (ALARP), within legal dose limits and within college dose constraints. Where reasonably practicable, and as advised by the College Radiation Protection Adviser, shielding will be employed in preference to other forms of protection that rely on management control, supervision or procedures.

Radiation User / User	A Radiation User / User is a person who is registered with the College Safety Department to undertake work using ionising radiations.		
Radiation Employer	The College is classed as a radiation employer where it undertakes work or practices involving the use of ionising radiations		
RPA	Radiation Protection Adviser	RPO	Radiation Protection Officer
IRR99	Ionising Radiations Regulations 1999	RPS	Radiation Protection Supervisor
ALARP	As Low as Reasonably Practicable		

Code of Practice

1 Restriction of Exposure

Shielding (radiation shielding) is normally used to protect users from external radiation exposure. Such shielding is considered an ‘engineering’ control since the protection relies on physical methods of control rather then administrative / management control. Physical control methods are preferred since they are obvious and it is clear when they fail or become ineffective (e.g. a perspex shield shatters). Administrative controls rely on users following instructions, for example ‘minimising exposure time’ or ‘maximising distance’.

Although administrative controls are an important aspect of the hierarchy of control (IRR99, Regulation 8(2), and may indeed also include physical measures (e.g. long handled tongs to increase distance), they depend almost entirely on the users’ actions to ensure the protection is implemented and optimised. On the other hand, suitable and properly installed shielding, be it a simple perspex shield or large lead wall, places less reliance on administrative controls other than the user following obvious instructions to work behind it.

This philosophy of protection is explained further in the following manual section: **IRPM-IRCP-005** *Restriction of Exposure.*

Safety Department
Imperial College London
South Kensington Campus
London SW7 2AZ
Tel: +44 (0) 020 7594 9423
safetydept@imperial.ac.uk
www.imperial.ac.uk

2 Radiation Shielding vs Functional Shielding

Whilst this section of the manual is concerned with radiation shielding which attenuates radiation by virtue of its properties, it is also worth mentioning functional shielding which also restricts exposure. Two examples of functional shielding are:

- Perspex shielding (or other material) which is used to protect users from splashes of radioactive contamination.
- X-ray Machine enclosures, some of which are designed to physically restrict access to the collimated beams, rather than 'shield' the x-rays.

A discussion of the second example can be found in the following manual section:

IRPM-IRCP-019 *X-Ray Equipment and Microscopes*

The rest of this guidance note will deal with radiation shielding.

3 Selection of Shielding

Group / Department Heads shall ensure that appropriate suitable and sufficient shielding is available to all users who work with ionising radiations in their area of responsibility. Their RPS shall ensure that such shielding is available for use in the laboratories and that it is adequately maintained and fit for use[1].

The RPA/RPO will endorse (or recommend shielding) after receiving the completed work registration forms for work involving ionising radiation and writing the radiological risk assessment (Form J). In this regard, the following guidance notes should be read and understood:

IRPM-IRCP-002 *Work Registration and Risk Assessments*

IRPM-IRCP-023 *Isotope Data* (for external radiation properties only)

4 Provision and Maintenance of Shielding

Department / group heads shall ensure that suitable and sufficient shielding is available, that it is adequately maintained and it has a suitable storage location when not in use. This should be considered as part of the funding (grant) process. Generally shielding requires low maintenance but inspections of integrity should be carried out at reasonable intervals.

[1] The presence of shielding material does not necessarily indicate that is it suitable. For example, the shielding may be of the wrong type for the ionising radiations present, or there may not be enough to adequately shield the trunk of the body.

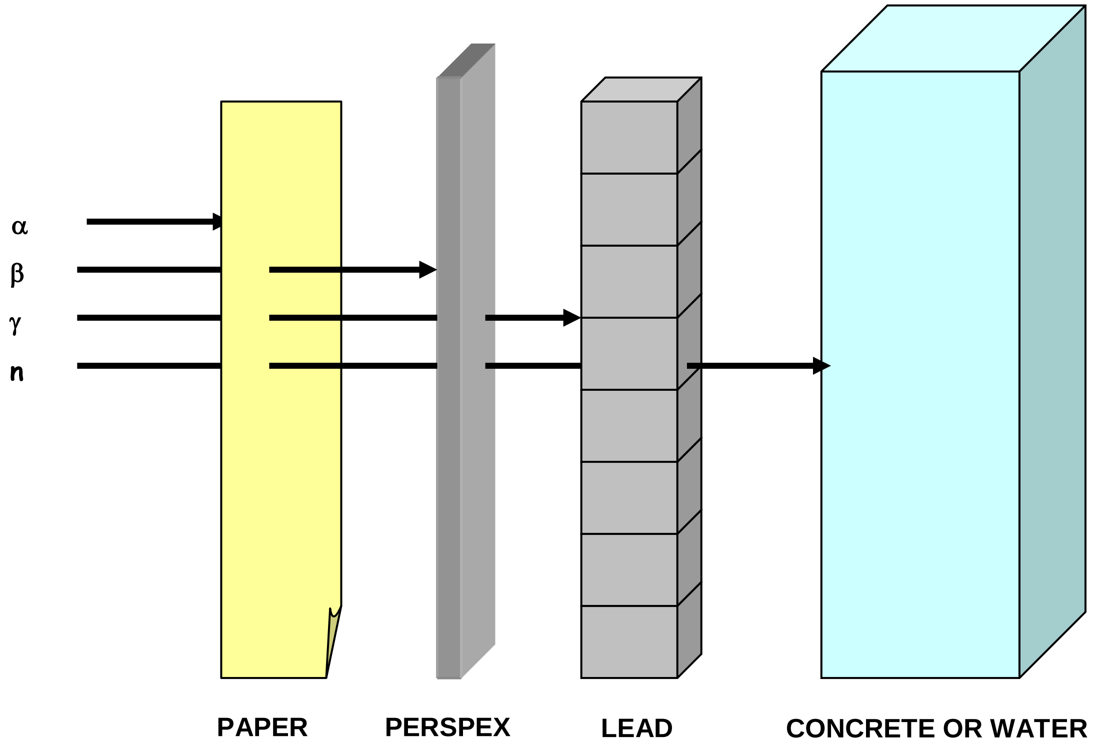
Imperial College London

Safety Department
Imperial College London
South Kensington Campus
London SW7 2AZ
Tel: +44 (0) 020 7594 9423
safetydept@imperial.ac.uk
www.imperial.ac.uk

Guidance

Shielding Philosophy

In general, shielding is used to reduce the exposure from high energy beta emitters (such as P-32) and x-ray / gamma emitters (e.g. I-125, Cr-51 or Cs-137). There are other more exotic shields, for example those used for attenuating neutrons (which will not be considered further). The following diagram summarises the options:



Examples of shielding

This guidance section provides an overview of some of the types and methods of shielding available. Whilst some degree of inference can be given to the title sections below ‘e.g. Beta Shielding (P-32) etc’, the actual selection must be based on the information contained in the completed work registrations and not exclusively by what appears in this manual section.

Imperial College London

Safety Department
Imperial College London
South Kensington Campus
London SW7 2AZ
Tel: +44 (0) 020 7594 9423
safetydept@imperial.ac.uk
www.imperial.ac.uk

Perspex Shielding ('Beta' Shielding, 'P-32 Shielding')

In general perspex (or acrylic) materials are used for shielding high-energy beta particles from P-32 and similar, and to a lesser extent P-33 or S-35 (lower energy beta emitters). Its low density and transparent nature makes it the ideal material, since it reduces the probability of Bremsstrahlung[2]

radiations whilst allowing an adequate view of the work area immediately in front of the shielded user.

The three examples below are particularly important shields for P-32 work.

- The general perspex shield should be set up to protect the user, and those around the user, from P-32 (beta) exposure. Special care should be taken to ensure that those working 'opposite' a P-32 worker (e.g. other side of the bench) are also protected (see diagram on next page).
- The perspex box should be used for storing P-32 waste (e.g. tips, gloves, tubes etc). They come in a variety of sizes. The small ones should be lined with a drawstring polyethylene bag; some of the larger ones can accommodate a sharps bin. Whatever size is used, special care must be taken when filling with waste since that waste needs to be removed again at a later date.
- The third picture shows an example of ependorf holders, (the ones shown also have mini-shields at the front edge). There are many different types of holder; all aim to reduce exposure by shielding the fingers and increasing the distance between the tube and finger.
- The above notes are for P-32, similar principles will also apply for P-33 and S-35 although the shielding requirements for similar levels of activity will be less.
- To completely absorb the beta radiation from P-32, the Perspex must be at least 10mm (1cm) thick.

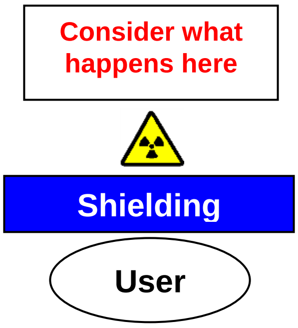
		
Perspex Shield	**Perspex Box**	**Perspex Ependorf Holders**

[2] Bremsstrahlung radiation is produced when high-energy electrons (i.e. beta particles) interact with dense materials. The resulting x-ray emissions can, in many cases, be more problematic than the primary beta radiation. Whilst thick, dense, shielding will attenuate the bremsstrahlung it is not very practical for P-32 and similar work. Thin 'dense' shields such as lead are likely to be problematic as bremsstrahlung might be significant. The solution is to use low-density materials which results in less production of the secondary radiations. Similar, but lesser, effects can be seen with P-33, S-35 and C-14.

Safety Department
Imperial College London
South Kensington Campus
London SW7 2AZ
Tel: +44 (0) 020 7594 9423
safetydept@imperial.ac.uk
www.imperial.ac.uk

Position of shield

Careful consideration must be given to the position of shielding, relative to the user and others situated locally. Shielding of the user should not be at the expense of shielding others. A common example is where shielding is placed in front of the work but not behind it. If the work is being conducted in a room with a solid back wall there is little problem[3]. However, if the work is taking place on an island bench, then there is potential for inadvertent exposure to those who face the 'back' of the work. This is illustrated in the schematic below.

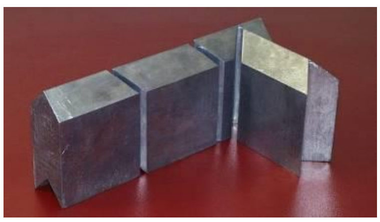


The diagram illustrates a shield set up in front of the radioactive source. The user may well be adequately shielded, whereas others opposite the work may not be.

Lead Shielding (*'Gamma' Shielding, 'I-125' Shielding, 'X-ray' Shielding*)

In general, lead (or lead impregnated) materials are used for shielding x-rays and gamma rays from I-125, Cr-51 and similar. Unlike perspex, lead shielding relies on its high density to provide adequate attenuation and reduction in exposure to users. Its high density means its mass is considerable for a given volume and therefore extreme care should be taken when moving such shielding around.

The first two examples below are particularly important shields for I-125, for Cr-51 lead sheet is required, (the use of lead bricks in most cases will be unsuitable as described below).

[3] This applies to beta emitters such as P-32. If high-energy gamma emitters are being used then even a solid wall may not prevent exposure to persons on the other side. If in doubt consult the RPA/RPO.

Imperial College London

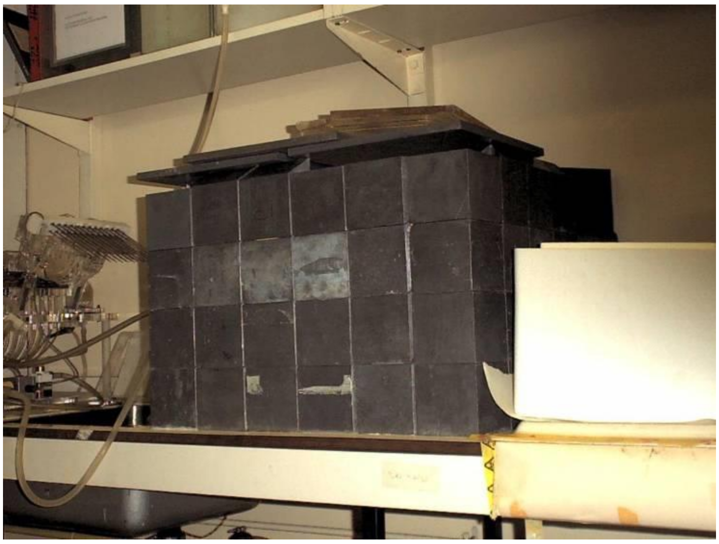
Safety Department
Imperial College London
South Kensington Campus
London SW7 2AZ
Tel: +44 (0) 020 7594 9423
safetydept@imperial.ac.uk
www.imperial.ac.uk

Leaded Perspex	Leaded Perspex Box	Lead Bricks

The following should be noted:

- The general leaded perspex shield should only be used for work with I-125 and should be set up to protect the user, and those around the user, from x-ray / gamma ray exposure. Special care should be taken to ensure that those working 'opposite' a user (e.g. other side of the bench) are also protected (see diagram in "P-32" section above). Unlike most P-32 type work, some extra thought must be given to transmission of x-ray / gamma rays through solid walls (and particularly through stud/partition type walls which afford little attenuation).
- The leaded perspex box should be used for storing x-ray / gamma waste (e.g. tips, gloves, tubes etc). Leaded Perspex boxes come in a variety of sizes. The small ones should be lined with a drawstring polyethylene bag; some of the larger ones can accommodate a sharps bin. Whatever size is used, special care must be taken when filling with waste since that waste needs to be removed again at a later date.
- The final picture shows an example of lead bricks. There may be some merit for using them in certain circumstances[4], but in most cases they are overkill and actually represent a significant manual-handling hazard. In addition, not all surfaces (or fume cupboard bases) are designed to take the weight of these bricks; a structural collapse could cause significant injury.

Unsuitable use and deployment of lead shielding is shown in the following diagram:



This picture shows a lead 'castle' which was constructed on a bench top. Whilst the user thought they were doing the right thing, the actual amount of lead used far exceeded the shielding requirements (its use was not ALARP[5]). The lead shielding had a mass of at least 300 Kg, which was most likely overloading the bench.

If significant lead shielding is likely to be required in new or refurbished laboratories, the following manual section should be consulted:

[4] For I-125 and Cr-51, at activity levels of less than 37MBq, there is probably little merit in using substantial lead brick shielding. However, where higher activities are used, or where higher energy emitters are present (e.g. In-111, Cs-137, Co-60, Na-22) then lead brick shielding may be justified. Please consult with the RPA/RPO for advice as required.

[5] ALARP (As Low As Reasonably Practicable). With respect to shielding ALARP was not being complied with since the amount of lead used (i.e. degree of protection) far exceeded the risk (exposure) being mitigated.

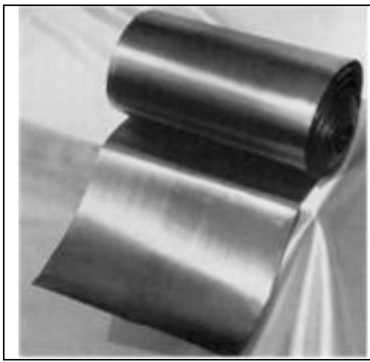
Imperial College London

Safety Department
Imperial College London
South Kensington Campus
London SW7 2AZ
Tel: +44 (0) 020 7594 9423
safetydept@imperial.ac.uk
www.imperial.ac.uk

Other important factors to consider with x-ray / gamma shielding:

- You will note that the beta and gamma perspex shields are similar. Clues to which is which are:
    - **Colour**: Beta shielding tends to be clear, whereas gamma (leaded Perspex) shielding will have a yellow like colouration.
    - **Mass**: Beta shielding will be noticeably lighter than photon shielding.
    - **Marking**: Most gamma shielding will be marked in some way (e.g. '*I-125*' or '1mm Pb equivalent').

- Most leaded perspex shielding found at the College will be designed for I-125 use (it may even be marked as '*for use with I-125 only*'). Care should be taken if this shielding is used for other x-ray / gamma emitters of higher energy. For example, Cr-51 is around 10 times as energetic as I-125. Therefore an 'I-125' designed shield will be 10 times <u>less</u> effective for the same quantity of activity. You may need to consider supplementing the leaded perspex with lead sheets or similar. If in doubt you should discuss your requirements with the RPA / RPO.



This diagram shows a roll of lead sheet that can be cut up and used to supplement your shielding requirements. You should be aware of lead handling requirements from a chemical consideration (i.e. COSHH) as well as recognise its substantial mass.

Shielding Thickness

It is possible to calculate the thickness of shielding required to attenuate exposures to satisfactory (ALARP) levels. However, for most College work shielding comes in standard thicknesses and these will normally be adequate (but this should be verified with monitoring). For beta shielding a thickness of at least 10mm will be appropriate. X-ray / leaded perspex gamma shielding (e.g. for I-125) normally comes as '3mm lead' equivalent or more. If you are unsure whether your shielding is adequate, or would like its performance verified by independent monitoring, then please discuss this with the RPA/RPO.

Other Shielding – Concrete

If other shielding is required, for example to attenuate neutrons or high energy photons, please contact the RPA/RPO for additional advice. This is particularly important at the design stage for

Imperial College London

Safety Department
Imperial College London
South Kensington Campus
London SW7 2AZ
Tel: +44 (0) 020 7594 9423
safetydept@imperial.ac.uk
www.imperial.ac.uk

new facilities where ionising radiations will be used (e.g. facilities where PET/CT scanners will be installed or PET isotopes will be used).

Gamma and x radiations are attenuated exponentially when they pass through any material and the dose rate after passing through a shield depends on the type of material used for that shield.

As mentioned above, lead is usually the material of choice to shield from gamma of x radiations, but when considering facility design, it may be that the amount of lead required is too great because of either financial and/or structural considerations. In such cases, concrete or a combination of lead and concrete could be the solution. The RPA must be contacted at the design/costing stage of projects so that suitable shielding calculations can be undertaken and shielding recommendations be made.

Neutron shielding is also complicated because a wide range of neutron energies can be generally encountered. Any shielding calculations have to take into account a number of different energy related reactions. Some of these reactions can also result in the emission of other ionising radiations (e.g. alpha particles or gamma photons). The RPA must be contacted regarding any proposed work involving neutrons so that shielding calculations can be made[6].

[6] This does not include work at the Imperial College Reactor Centre.