I. Introduction

Any work with radioactive substances raises particular health and safety issues. This handbook outlines the factors that must be taken into account when working with exposed radioactive sources. It also includes comprehensive guidance on how to design a radioisotope work area, from risk assessment to furnishing, and sets out the levels of protection required for radioactivity workers.

Work with radioisotopes in any research or teaching establishment must be carried out under specified conditions, and in a facility designed to prevent or adequately control the exposure of those working with the isotopes and anyone else nearby. People working outside the immediate area and visitors must also be protected from exposure to ionising radiation, and adequate controls must be put in place to safeguard the environment.

Ionising Radiations Regulations 1999 (SI no. 3232) and the Approved Code of Practice and Guidance (ISBN 0 7176 1746 7) detail the safe working-practice rules that govern any work with radioisotopes. Under the Radioactive Substances Act 1993, establishments intending to work with sealed or unsealed radioactive sources must first obtain one or more certificates of registration to hold sources, and of authorisation to accumulate and dispose of radioactive waste. These certificates are issued by either the Environment Agency (EA) or the Scottish Environment Protection Agency (SEPA). Local rules, if they apply, and appropriate training measures must also be implemented before any work with radioactivity can begin.

This handbook is intended only as a guide. When building or refurbishing a radiochemical laboratory, these guidelines must be used in parallel with advice from a qualified radiation protection adviser (RPA) and the local radiation protection supervisor (RPS). Building or refurbishing any facility may also need to take into account other physical, biological and chemical hazards. Further advice from other specialists may therefore be required.
2. Preliminaries and management issues

2.1 All work with ionising radiations must:

- be subject to working procedures or, where required, local rules;
- comply with IRR99 secured by local radiation protection supervisors (RPS) and line management; and
- if appropriate, be subject to additional written arrangements.

High-risk activities using ionising radiation must be conducted in suitable segregated facilities with sufficient engineering controls to minimise the risk of both internal and external contamination and exposure.

Suitable personal dose-measurement and area-contamination monitoring procedures should be in place to confirm the efficacy of local control measures.

Where ionising radiation is used all areas will be subject to periodic inspection and audit to confirm the efficacy of local control measures.

2.2 Risk assessment/management control system for designation of laboratory grade

Risk assessments and control measures

The risks associated with any new activities involving ionising radiation must be assessed before work can begin. The risk assessment will evaluate whether the area being considered for radioactive work is suitable, and will greatly help planning teams in designing new facilities for radioactive work. The risk assessment must consider all the hazards involved in the activity, including non-radioactive work-related hazards. The assessment will determine not only the controls needed to protect people directly involved with the work, but will also consider whether other staff, visitors and members of the public will be exposed to any risk from the work. The RPS and/or the RPA will normally help the principal investigator (PI) to conduct the risk assessment.

The main points that the risk assessment should consider include:

- the properties of the radioisotopes to be used;
- the quantities of radioisotopes handled and the frequency of procedures;
- the grading and suitability of laboratory facilities;
- the extent of any external hazard;
- the extent of any air contamination hazard;
- who may be affected by any release of activity;
- manufacturers’ or suppliers’ guidance relating to storage, dispensing and handling of the material;
- the risks associated with different waste-streams;
- the effectiveness of general measures taken to restrict exposure, such as shielding, containment, monitoring, and protective clothing.

Note: Where the Construction (Design and Management) Regulations 1994 apply, the client should liaise from the outset with the Planning Supervisor in drawing-up the safety plan that will address the hazards associated with the design, construction and maintenance of a new or refurbished facility.

2.3 Consulting users

To ensure that the facility meets functional requirements

It is important that at least one person representing the users should be appointed to liaise with the design team and Estates Management. Regular and frequent meetings must be held throughout the duration of any new project.
3. Designation of radiation work areas

There are three main area designations for work with radioisotopes: controlled, supervised and registered.

3.1 Controlled areas

Controlled areas are designated as such because people entering the area must follow special procedures to prevent them from receiving a significant radiation exposure over a period of time. These procedures will ensure that exposure rates are as low as is reasonably practicable (ALARP) and in any case will not reach the maximum permissible level for controlled areas.

Such procedures normally follow a detailed system of work that sets out how the tasks should be undertaken in a way that restricts significant exposure to radiation. The main purpose of designating controlled areas is to help ensure that the control measures taken, effectively prevent or restrict routine and potential exposures. This is achieved by controlling who can enter or work in such areas and under what conditions.

A controlled area is one in which the risk assessment indicates one of the following:

- effective doses in excess of 6 milliSieverts are likely to be received in a year (6mSv/yr);
- equivalent doses in excess of 3/10 of other relevant limits are likely to be received in a year; or
- where special written procedures, specific to the area, need to be followed in order to restrict doses to less than 6mSv/yr;

It is the employer’s duty to designate controlled areas. The following points should be considered when deciding to designate an area as controlled:

- who is likely to need access to the area;
- what level of supervision is required;
- the properties of the radiation sources in use and the extent of the work in the area;
- the likely external dose rates to which anyone might be exposed;
- the likely duration of exposure to external radiation;
- the physical control methods already in place, eg, permanent shielding and ventilated enclosures;
- the importance of following a procedure closely in order to avoid receiving significant exposure;
- the likelihood of contamination arising and being spread unless strict procedures are closely followed;
- the need to wear personal protective equipment in that area; and
- the maximum dose estimated for work in the area.

In addition to these considerations, it may be necessary to designate an area as controlled if:

- it is possible that people, such as office staff, whose work does not normally involve ionising radiation might have access to that area;
- normal control measures need to be suspended for work such as maintenance or changing the radioisotope being used;
- people are likely to be exposed to surface or airborne contamination at levels significantly greater than appropriate derived working levels or derived air concentrations; or
- respiratory protective equipment must be worn while working in the area.

3.2 Supervised areas

Supervised areas are those where a risk assessment indicates one of the following:

- effective doses are likely to exceed 1mSv/yr, but are less than 6mSv/yr;
- effective doses are likely to exceed an equivalent dose in excess of 1/10 of any other relevant dose limit; or
- where working conditions need to be kept under review to ensure that designation as a controlled area is not required.
A whole laboratory, suite of laboratories, or part of a laboratory can be designated as a supervised area. The decision to designate an area as supervised depends both on the assessment of likely doses in that area and the probability that conditions might change. For example, an area may need to be kept under review and therefore be designated as supervised, because of the possibility that radioactive contamination might spread. However, it is not necessary to designate a supervised area outside of every controlled area. For example, if a controlled area has been designated on the basis of external dose-rate, and conditions in adjacent areas are unlikely to alter significantly, a supervised area will not be necessary unless a person in the adjacent areas is likely to receive a dose in excess of 1 mSv/yr.

In laboratories where only small quantities of unsealed radioactive substances are used, it may not be appropriate to designate the whole room as a controlled area to ensure that those who enter or work there follow specific procedures. However, in such circumstances there will be general arrangements for preventing spillages as far as possible and for cleaning up any contamination arising from a foreseeable spillage. Normally, the employer should designate at least part of the laboratory as a supervised area if contamination could build up over a period of some weeks as a result of not following these arrangements. Boundaries that are convenient for the supervised area can be assigned. Once such an area has been designated it is subject to all the legal requirements applying to supervised areas.

3.3 Registered areas

Registered areas are those where radioactivity is used, but that do not require designation as either controlled or supervised areas, because effective doses to personnel are unlikely to exceed 1 mSv per annum. For example, a designated bench within a laboratory, or the entire laboratory could be a registered area.

For all designated areas, the appropriate radiation hazard signage must be displayed and work activities must be reviewed on a regular basis.

4. Design of radioactive work areas

4.1 General requirements

Apart from the general features of design expected in any good laboratory facility, special attention must be paid to the ventilation and surface finishes. Ventilation systems may require efficient filtration units to remove radioactive particles before discharge. In the case of radioactive gases, which would not be removed by filtration, care must be taken to ensure that the outlets are located so that such gases are adequately dispersed.

Surfaces in a radioactivity work area should be smooth and unbroken and be made from materials that are chemically inert, non-absorbent and water-repellent. Possible decontamination problems that may arise should also be considered. Materials that are either easy to decontaminate, or can be conveniently removed and replaced must be used.

4.2 Specific requirements

Radioisotope laboratories and work areas should be sited in a suitable position and located away from public thoroughfares. A radioisotope work area can be within other laboratory space, for example, a dedicated marked area, or a specific laboratory segregated from other areas. It cannot be in, or entered from, an administrative or recreational area. Any issues regarding ease of access for services and their maintenance must be considered when deciding where to site the laboratory or work area.

4.3 Maintenance

To ensure the continued safe working of the facility

Consider your maintenance capability! As a general rule, over-complicated systems should be avoided. The design should be made as simple as possible from the points of view of laboratory structure and mechanical and electrical installations.
4.4 Space norms and allocations

To ensure the provision of adequate space for each worker

Adequate space must be provided to allow for comfortable and safe use of the facility by all personnel, while minimising the impact of their activities on each other and on the function of safety equipment (e.g., fume cupboards or microbiological safety cabinets [MSC]). As a guide, 10m$^2$ should be enough to accommodate one person and the standard equipment (fume cupboard or MSC, benching, incubator, freezer and centrifuge) required in a radioisotope laboratory or work area. A second person may need slightly less space as some pieces of equipment may be shared.

Space lost to equipment and the nature of the activities to be undertaken must be taken into account when calculating space requirements.

4.5 Floors

The floor should be covered with an impervious surface such as a continuous sheet of PVC or linoleum at least 2.5mm thick.

The covering should extend in an unbroken sheet up the adjoining walls to a height of about 15cm. All edges at the walls should be sealed or welded to prevent spilled materials from seeping behind them.

Joints between sheets are not recommended, but may be permissible if they are welded and inspected to make sure that there is no seepage path for contamination.

As an alternative to a sheet material covering, an epoxy resin coating may provide an acceptable finish on smooth concrete.

Any non-slip sealant material used to make cleaning easier may be applied, provided that spilled materials can be easily removed during the decontamination procedure. Generally, epoxy resin coatings are easy to decontaminate.

4.6 Walls and ceilings

The walls and ceilings should generally be smooth and painted with a hard gloss or high-quality waterproof vinyl emulsion to facilitate cleaning (B S 4247 Part 2). Stippled surfaces or paint finishes applied to unplastered concrete blocks are unacceptable.

Suspended ceilings may cause problems due to penetration of contamination.

Joints should be sealed or filled with silicone-type materials to facilitate cleaning (or removal in the event that decontamination is not possible). Service penetrations in walls and ceilings should be sealed and coved.

Caution: Many paints undergo chemical or physical reactions with certain radioisotopes. A more important consideration may therefore be the ease with which contaminated paint can be stripped off rather than its cleaning properties. A known problem occurs with chloride ions, which may bind irremovably to painted surfaces.

4.7 Doors

It is essential to secure radioactive materials. Doors should therefore usually have locks to ensure safe-keeping, or to restrict access in the event of a major spillage. Doors leading off public places and which are frequently opened may be made more secure by installing a keypad lock. Some establishments may provide a high level of security for a building and/or an entire site, rather than for an individual laboratory within a building.

Doorways must be large enough to allow installation and removal of equipment, and doors must, where necessary, comply with fire-protection standards.

4.8 Benches

Work surfaces should be smooth, hard and non-absorbent, and have necessary heat and chemical resistant properties; Trespa™, Corian™ and stainless steel are suitable materials. Benchtops should have a coved ‘up-stand’ at the rear against walls, and should be continuous.
wherever possible. Where this is unavoidable they may be butt-jointed and all gaps and joints sealed with a silicone-based material. A raised front lip can help prevent a spillage running off the bench on to the floor and is readily provided with stainless steel covered tops.

Depending on the type and quantity of radioactive materials used, the problems involved in decontaminating certain materials used for bench surfaces may be relevant. For example, Corian™ apparently binds iodine (e.g., I-125) in several chemical forms; Melamine fixes sodium ions (e.g., Na-22) under some conditions; stainless steels may bind phosphate (e.g., P-32) or chromium (e.g., Cr-51) firmly, and may be very difficult to decontaminate.

Dedicated bench areas should be reserved for radioactive work and clearly marked as such. To minimise spills and spread of contamination it is good practice to work in plastic or metal trays on bench tops and, more particularly where larger quantities of radioactivity are involved, in dispensing/preparation cabinets. Disposable absorbent coverings such as Benchkote™ may similarly be useful, but only as a supplement rather than an alternative to proper bench surfaces. Such coverings may therefore best be used inside trays.

4.9 Fume cupboards

May be required for controlling exposure to radioisotopes, hazardous or flammable chemicals

Most work that requires a fume cupboard can also be conducted inside a Class I MSC. Installation of a fume cupboard must be subject to a risk assessment by the users, and if installed consideration must be given to whether HEPA filtration is required.

Note that any filters on the outlet side may become contaminated with radioactive materials and will need to be treated as radioactive waste when replaced.

If a fume cupboard is to be used for containment when working with substantial quantities of a hard gamma-emitter then the plinth will need to support a considerable amount of lead shielding (possibly up to 1,000kg).

4.10 Windows and vision panel

To allow access to natural light and for safety so that people working inside can be seen by those outside

Where opening windows are fitted, care should be taken that any release of radioactivity will not affect anybody immediately outside. Open windows should not be used as intentional discharge routes.

Vision-panels must be located to allow the workers inside the laboratory to be seen at all times by those outside without the need to enter. These vision- or window-panels must comply with fire and security requirements.

External windows must be secured. They should preferably be double-glazed and the internal surfaces should be smooth to allow cleaning.

4.11 Ventilation and containment

Dispensing or preparing radioactive materials that may cause airborne contamination should be carried out under conditions that will prevent dispersal of the substances. In particular, volatile radioactive materials should never be used in the open laboratory, but only in appropriate containment such as a fume cupboard. Re-circulating ventilation systems may not be appropriate for volatile radioactive materials.

General dilution ventilation (air circulation) should be provided in all radioactive laboratories. Where small quantities of radioactive materials are used, an extractor fan mounted in a window or a wall will achieve this. Where larger quantities of radioactive materials are used, a guiding principle for effective contamination control is that air movement from less-contaminated areas to more-contaminated areas should be maintained. This may be achieved for example by extracting from a general laboratory area, through a fume cupboard, to a discharge stack.
A contained workstation (Class I–III MSC or fume cupboard) should be used for dispensing or manipulating large quantities of radioactive materials. Adequate ventilation by continuous movement of air into the workstation should be checked regularly, preferably by measurement with an anemometer. Airflow criteria for fume cupboards are specified in BS 7258.

Internal and external surfaces should be smooth, hard and non-absorbent and have the necessary heat and chemical-resistant properties.

Room ventilation and fume cupboard extract/supply systems must be integrated, and warning-labels placed on fume-extract ducts and fans. Filters are not normally required in the extracts of laboratory fume cupboards, but monitoring of the effluent, e.g., radioiodine, may be necessary.

4.12 Access controls
To restrict access to authorised users only
Access to facilities with designated radioactivity work areas should be controlled locally, through a swipe- or proximity-card, push-button system, or a key. If connected to swipe-card systems then these must remain locked in the event of fire. However, emergency-release mechanisms (preferably mechanical) must be installed to allow people to leave at any time.

4.13 Hand-wash basins
Hygiene facility for hand washing
A designated hand-wash basin should be provided. This must not be used to dispose of radioactive substances (other than traces from hand washing).

Separate hand-wash basins must be as close to the exit as possible so that staff do not need to touch any potentially contaminated surfaces after washing their hands.

4.14 Hand-wash basin taps
To allow operation without the need for using hands
Elbow, foot, knee or passive infra-red operated systems which do not require handling should be used. Warm water must be pre-mixed to a comfortable temperature and the pressure limited to prevent accidental splashing.

4.15 Soap and towel dispensers
Dispensers for soap (preferably hands-free) and disposable paper-towels should be permanently installed beside the basin.

4.16 Emergency shower
In most cases, it will not be necessary to install an emergency shower within or near a radioisotope laboratory. Only hand-held flexible hose showers should be routinely installed, the most convenient place being near the hand-wash basin in the lobby. The alternative option of installation within the laboratory itself could also be considered.

4.17 Changing facilities
At the very least, somewhere to hang lab-coats should be provided near the laboratory entrance. It is usual to provide a lobby/changing area for higher-grade laboratories. Generally a controlled-area laboratory will require a changing area demarcated from the laboratory by floor markings or step-over barrier.

4.18 Lighting
Adequate lighting should be installed throughout the laboratory. In particular, this should give 500 Lux at the bench, to enable operators to see spillages easily. Careful positioning of light sources is crucial to avoid shadows over workstations.
Lighting should be suitable for 'wet areas'. The covers and outer surfaces should be resistant to chemicals or other corrosive substances that may be used.

### 4.19 Light switches

Light switches can be sited inside or outside the laboratory, but should be installed in such a way that all wires and conduits entering the laboratory are properly sealed to prevent any contamination from escaping.

### 4.20 Temperature control

**Comfort of workers and effective performance of equipment**

A comfortable working environment must be provided. Thermal comfort is particularly important and must be carefully considered. Simplicity must be the overriding consideration when designing the environment.

### 4.21 Noise levels

In providing a comfortable working environment, noise output from all equipment must be considered and adequately controlled.

### 4.22 Physical demarcation of controlled areas

The main purpose of physically demarcating a controlled area is to help restrict unauthorised access. In assessing whether suitable measures have been taken to restrict access, one should consider the nature of the work and the likelihood that the measures taken will restrict access to people who are allowed to enter the area. To be effective, the method of demarcation should clearly indicate the extent of the controlled area, leaving no room for doubt.

In most cases it will be appropriate to use physical features, for example, existing walls and doors. Employers should provide temporary barriers where such physical features cannot be used. These barriers will usually need to be supervised. In such circumstances, the areas must be clearly delineated by other suitable means so employees (and other people as necessary) are aware that these areas exist.

### 4.23 Warning signs

Adequate and accurate safety signage must be provided. Details of emergency contact arrangements must also be clearly displayed.

Warning signs, clearly and legibly marked with the word "Radioactive", with the Ionising Radiation symbol conforming with BS 3510: 1968 or ISO 361, and any other necessary information (contact person, telephone number, etc), should be placed on doors, cupboards, equipment, refrigerators, working areas, drainage pipes, sinks, storage facilities, sewers, exhausts, etc. as appropriate. A sign on the laboratory door indicating the maximum holdings of each radioisotope is also useful. Warning signs should only be used when there is a real possibility of contamination; in particular, indiscriminate use of radioactive warning tape should be avoided.

### 4.24 Control over entry into designated areas

The employer who designated a radioactive work area is responsible for controlling access to that area. If the employer in control of a site hands the control of a particular area to another employer, for example a contractor undertaking maintenance work, the second employer is then responsible for controlling access.

Different requirements apply to access by classified radiation workers and non-classified individuals. There are additional requirements concerning access by classified persons who are outside workers. Any employee who enters a controlled area will require appropriate instruction.

In many cases, physical barriers and warning signs may be sufficient to restrict access to a controlled area when backed up by appropriate training and instruction. However, in some cases
the employer in control may need to arrange for supervision of access points into the area to ensure that appropriate checks can be made.

4.25 Seating

The surfaces of stools and chairs should be non-absorbent or upholstered in non-absorbent material.

4.26 Communications

Normal and emergency communication

Data points must be provided as required by users. If significant numbers of sockets are needed, installing a hub within the laboratory space to minimise the penetrations through the lab seal might be the best solution.

Hands-free telephones/intercoms are preferred as touch systems can become contaminated. The users should also consider the need for an emergency panic-button, web-cams or CCTV.

5. Use of radioactive work areas

5.1 Personal protective equipment (PPE)

Gowns, gloves, masks – provision for supply and disposal

Sufficient lab-coat hooks must be provided either within the lobby, if there is one, or in the laboratory itself. Separate storage space to accommodate clean PPE and used PPE awaiting disposal or cleaning, must also be provided within the lobby or laboratory.

5.2 Alarm systems for equipment

For example:
- To prevent samples from spoiling in the event of a freezer or fridge failure.
- Failure of local exhaust ventilation/fume cupboards.

5.3 Decontamination of surfaces (walls, floors, benches)

To render surfaces free of contamination

All surfaces will need periodic decontamination using a proprietary decontaminant such as Decon 90™ and therefore must be resistant to any such substances.

5.4 Monitoring equipment

Detection of personal and area contamination

Suitable, calibrated contamination monitoring equipment must be available within the work area. This is to enable personnel to monitor themselves after work with radioisotopes, and to monitor the work area before and after working there to ensure that no contamination is transferred to clean areas.
5.5 **Equipment other than microbiological safety cabinets**

Eg, centrifuges, incubators, freezers, fridges

The users will select these. Consideration will need to be given to service supply, eg, CO₂ gas. There will be safety considerations such as centrifuge rotor-sealing etc.

Heat output from equipment must be taken into account when considering cooling requirements.

5.6 **Tacky mats**

Tacky mats, installed in laboratory doorways, may be useful in preventing the spread of contamination. Monitoring of the mats may give early-warning of a contamination problem.

6. **Waste management**

6.1 **Waste disposal sinks and drainage pipes**

Sinks for the disposal of radioactive waste-water should be constructed of suitable material. Stainless steel is preferred for most applications. Where possible, combined sinks and draining boards should be used, with rounded front edges and a coved 'up-stand' at the rear against walls. Ideally an easily decontaminated rear splash-plate should extend a reasonable distance up the wall behind the sink. Side splash-guards may also help. Both hot and cold water pressures must be limited so that splashing of the users is limited. Taps can be of the conventional laboratory type touched by gloved hand.

Drainage-system materials should take into account the possible build-up of contamination on surfaces. Note that phosphate ions may bind strongly on to stainless steel and this may cause problems in laboratories where P³² or P³³ is used in quantity. Similar problems may arise where old fashioned sinks have been sealed with putty or in hard-water areas where a calcium phosphate layer may be precipitated in the sink. Borosilicate glass sanitary-ware may be appropriate in some circumstances.

Small diameter U-shaped or bottle traps should be used instead of large traps or catch pots, to avoid radioactive sediments from building up. The drain should be connected as directly as possible to the main foul-water sewer leaving the building. Holding tanks are generally undesirable because of sedimentation, but may be necessary for other reasons, for example to comply with chemical-discharge consent conditions. The discharge route should be mapped and recorded for future reference in case maintenance on the system is required.

**Note:** All drainpipe materials may retain specific radioisotopes. The most generally useful type – "vulcanene" – fixes iodine very strongly, which may be significant where radioiodides have to be disposed of through vulcanene drains. Drainage pipes for radioactive effluent should be labelled with the ionising radiation symbol (trefoil) up to the point at which their contents are diluted substantially with frequently flowing, non-radioactive effluents. This is to alert maintenance staff in order to prevent
unauthorised disposal of any contaminated pipes that are removed during maintenance work. Pipes should be well-supported along a suspended run which should be down-sloped to prevent radioactivity from accumulating and, where reasonably practicable, should be made accessible – for example by the use of removable panels – and inspected regularly to assure their integrity.

6.2 Radioactive storage facilities (including waste)

Adequate storage space to keep essential equipment should be provided in order to minimise the cluttering of working areas and reduce the risk of spreading contamination. An area should be set aside to store equipment awaiting decontamination.

All fridges and freezers used to store radioactive materials should be lockable, kept locked, and identified with appropriate signage, especially in large general laboratories, unless they are guarded. Fridges and freezers should be regularly defrosted. It should be noted that volatile radioisotopes, in particular tritium, might accumulate in the ice, so it is good practice for the user to check this periodically.

Waste-disposal bins in the laboratory (used for storing solid radioactive waste awaiting disposal) should be made from a robust material that provides adequate shielding, eg, 10mm Perspex for P-32, and should preferably be foot-operated. The lid should be closed when not in use and the contents in the bag sealed or secured before removing them from the bin. All sharps, bottles, tubes, etc. should be placed in sharps containers to ensure safe handling. Bins located outside the control of the user must be secure to prevent misuse of the contents.

Adequate storage space (eg, a bunker or store-room) should be available for radioactive waste either inside or outside the laboratory. The storage space must be kept locked and may need to be kept under surveillance.

7. Maintenance and servicing

7.1 Maintaining the facility

Levels of servicing to any new facility must always be dictated by the levels of support that can be provided by the institution.

Radioisotope work areas may require careful and extensive decontamination in order to allow access by maintenance personnel. If this needs to be done frequently then the resulting loss of effective time available for research can be considerable.

The work within a radioisotope work area will need to be run down to allow performance testing of fume cupboards or microbiological safety cabinets.

7.2 Cleaning of the room

Radioisotope work areas should be monitored and cleaned regularly. The design of the laboratory and choice of materials must make it easy to clean such facilities quickly and often.
8. Commissioning

The laboratory and its equipment must be tested to ensure that the standards specified by the research group, department, college, Health and Safety Executive, and Environment Agency have been met before work begins. The general standard of workmanship must be carefully assessed, and a number of key aspects must be tested.

- The work area must be contained – ie, radioactivity must not be able to inadvertently escape. This means that all walls, floors and work surfaces are sealed and continuous. All seals around windows, pipe-work, electrics, etc. must be visually checked and possibly smoke tested. A competent commissioning team together with representatives of the contractors must carry out these tests.

- Where applicable the exhaust and supply ductwork must be pressure tested and certified for leak-tightness. This must be done by a specialised engineer. All seals around HEPA filters, fans and dampers must also be checked, and the effectiveness of the dampers in preventing reverse airflow established.

- All control systems must be fully tested and commissioned by the installing engineers. This must be proved and demonstrated to the client. This includes all shutdown and start-up controls, damper controls, flow adjustments and remote cabinet switches.

- All HEPA filters where fitted must be tested by certified engineers to ensure that they meet the required specifications after installation.

- All alarm systems, for example for air-systems failure, electrical failure, fire or improperly opened doors must be checked.

- All environmental control systems must be tested while all possible temperature-altering pieces of equipment are in operation.

- Microbiological safety cabinets must be fully commissioned and performance-tested to BS 5726 and BS EN 12469:2000. For open-fronted cabinets the operator-protection test must be conducted under conditions that mimic those encountered during normal use as specified in the Advisory Committee on Dangerous Pathogens (ACDP) publication, The management, design and operation of microbiological containment laboratories (page 62). An independent testing engineer must perform these tests.

- Fume cupboards must be fully commissioned and performance tested.

- Monitoring equipment must be performance-tested and calibrated before it is used.
Acknowledgement

We would like to thank the Association of University Radiation Protection Officers for the use of their document *Guidance Notes on Working with Ionising Radiations in Research and Teaching (2000)*.