THE UNIVERSITY OF SUSSEX

SAFETY COMMITTEE
LOCAL RULES FOR THE CONTROL AND USE OF X-RAY EQUIPMENT
SSC/48/2
Revised 2011 by Mark Roe

Summary of the Fundamental Local Rules for X-ray Equipment

1. Under the requirements of the Ionising Radiations Regulations 2017 each X-ray enclosure is deemed to be a CONTROLLED AREA.

   A controlled area is any area which has been identified by a risk assessment as an area in which,

   a) it is necessary for any person who enters or works in an area to follow special procedures designed to restrict significant exposure to ionising radiation in that area or prevent or limit the probability and magnitude of radiation accidents or their effects; or

   b) any person working in the area is likely to receive an effective dose greater than 6mSv a year or an equivalent dose greater than 3/10 of any relevant dose limit referred to in schedule 4 in respect of an employee aged 18years or above.

2. Entry by any part of a person into each controlled area whilst the beam is open is only permitted under the terms of a written safe system of work (PERMIT TO WORK CERTIFICATE).

3. A copy of each Permit to Work Certificate must be sent to the University Safety Service BEFORE the work with X-rays is commenced.

4. Each user of X-ray equipment must have read the Local Rules, (except for undergraduate teaching experiments - see 9 below).

5. ONLY licensed persons may use X-ray equipment. The X-Ray equipment must only be used in „normal" mode.

6. The nominated person and/or service personnel must have an X-ray radiation monitor (in an operational condition) close to their working position, throughout any period of time spent in the X-ray room when servicing the X-Ray equipment.

7. X-ray users must use the monitors to make frequent checks for leakage of radiation. They must also pay careful attention to the state of the equipment - checking for failure of components, e.g. micro-switches, shutters, warning lamps.

8. Users are reminded of the need to SEEK HELP and advice if they are in any doubt as to how to proceed safely.

9. **Undergraduate Safety:**

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Short revision by Angelina Janus 2022

(a) Project work is governed by this Local Rules document.

(b) Safety arrangements for undergraduate teaching are summarised in Section 6.1 table 1 and section 8.2 of these Local Rules.

1. INTRODUCTION

1.1 Local Rules

The University of Sussex Local Rules for the Control and use of X-ray Equipment deals with all X-ray equipment, but is mainly targeted at the control and use of the equipment used for X-ray crystallography, X-ray diffraction and X-ray spectrometry.

Where X-ray equipment is to be used which does not fall into the above categories, advice must be sought from the University Safety Service.

The Local Rules for the Control and Use of X-ray Equipment should be regarded as an extension of the University's general Local Rules for work with radioactive materials and ionising radiation, document SSC-48-1, revised 2009, titled **'Local Rules for Working with Radioactive Materials and Ionising Radiation'**

SSC-48-1 should be consulted for regulations dealing with ionising radiation, where the equipment or materials involved do not fall within the Rules for the Control and use of X-ray Equipment.

1.2 Forward Planning and Structural Requirements

1.2.1 Any resiting of X-ray equipment, or bringing new X-ray equipment onto the University campus must only be undertaken in consultation with the School appointed Radiation expert and the University Safety Service.

1.2.2 If two X-ray sets are operated from a common control panel, it is vital that there must be a clear indication as to which set is being energised.

1.2.3 Each X-ray room or X-ray facility must be provided with a master switch (isolator) which can be operated in the event of an emergency within the facility.

1.3 Need to Obtain an X-ray Licence

All potential users of X-ray equipment (except undergraduates undertaking a one-off course work experiment) must obtain a University of Sussex X-ray Licence. These are obtainable from the University Safety Service. See section 8.3 for where the requirements for these licences apply

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2. RADIATION PROTECTION UNITS

2.1 Absorbed Dose

The unit of absorbed dose is the Gray (Gy). The energy absorbed at the exposure area for 1Gy = $1Jkg^{-1}$.

2.2 Dose Equivalent

Since equal absorbed doses from different radiations, e.g. X-ray, neutrons, can give different amounts of biological damage, it is necessary for radiation protection purposes to derive a unit, the unit of dose equivalent, which takes into account this effect. Biological damage, for equal absorbed doses from different radiations depends upon the linear energy transfer of the radiation, i.e. the rate of energy deposition per micrometre travelled by the radiation.

To convert from absorbed dose in Gy to dose equivalent in Sievert (Sv), the absorbed dose is multiplied by a quality factor Q, which represents the linear energy transfer of the radiation

In the case of X-rays Q = 1, and hence an absorbed dose of 1Gy would give a dose equivalent of 1Sv. Throughout these Local Rules the units Sv, mSv or Sv will be used.

3. HAZARDS FROM X-RAYS

Equipment used for X-ray optics, produces intense beams of low energy X-rays,

e.g. at 10cm dose equivalent rate Sv s^{-1} for an X-ray tube operated at 40keV and 10mA

$$= \frac{0.5 \times 40 \times 10}{10^2} = 2\text{Sv per second}$$

A 5 second exposure of a hand to this dose equivalent rate (10Sv) would give rise to a mild to severe skin burn which would show within about 10-12 hours after exposure. A 100Sv dose would probably cause severe tissue breakdown, and may necessitate finger amputation.

The above effects are termed acute or short-term effects. Radiation also has the potential to induce cancers.

Keeping doses below the threshold for skin reddening will ensure that no acute skin damage occurs. Unfortunately, there is no threshold for cancer induction and, hence, no safe dose of radiation.

Every effort must, therefore, be made to keep X-ray exposure to an absolute minimum.

In general terms, this is not difficult to achieve in practice. The radiation can be easily detected using simple monitoring equipment, and since low energy 30-60 keV photons are used for X-ray optics, research workers can be easily protected by shielding.

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4. PROTECTION STANDARDS

The limits on effective dose (dose to the whole body) under IRR99 are:

- for employees aged 18 years or over,

  Whole body dose 20 mSv in a calendar year,

  To an organ e.g. skin 500mSv in a calendar year,

  To the eye 150 mSv in a calendar year

- for trainees 16-18 years of age,

  Whole body dose 6 mSv in a calendar year,

  To an organ e.g. skin 150mSv in a calendar year.

  To the eye 50 mSv in a calendar year

- for any other person, including members of the public,

  Whole body dose 1 mSv in a calendar year,

  To an organ e.g. skin 50mSv in a calendar year.

  To the eye 15 mSv in a calendar year

N.B. The dose limit for the skin applies to doses averaged over an area of skin not exceeding $1cm^2$.

In a study conducted by the Association of University Radiation Protection Officers (AURPO) 230 X-ray sets in 27 Universities were examined for a 10-year period. In that time only 18 exposures to X-rays were recorded and in only 6 of these cases were doses to the hands above 150mSv, i.e. only one significant exposure per 2300 workers per year. For this reason it has been decided **not to designate** University of Sussex X-ray users as classified persons.

5. LIKELY CAUSES OF ACCIDENTAL EXPOSURE

In the AURPO study, causes of accidental over-exposure were divided evenly between human error and equipment failure.

Chief causes were:
- failure to have the equipment effectively managed, i.e. failure to have each X-ray set under the control of a **Nominated Person**;
- failure to control the equipment during maintenance operations;
- failure to monitor for X-rays;
- failure to have an **'X-rays on'** warning sign;
- microswitches jamming in the shutter open position;
- sets developing electrical faults and generating X-rays even when the equipment is apparently switched off.

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6. LEGAL REQUIREMENTS, CODES OF PRACTICE AND GUIDANCE NOTES

6.1 The Health and Safety at Work Act, 1974

This Act requires users of X-ray equipment to take care to keep to a minimum the exposure of themselves and any other persons likely to be affected.

It calls, not only for safe and well maintained equipment, but also for the hazards to be identified and **safe systems of work** to be used.

There is a clear requirement for users to receive **information** concerning the safe use of the equipment and the hazards from X-rays, to receive **instruction** in safe methods of working (safe systems of work) and, where necessary, to receive adequate **training** and effective **supervision.**

The overall responsibility for meeting the last four requirements listed above rests with the line management. However, the following division of duties is suggested in Table 1.

TABLE I

Requirements for the Following Major Groups of X-ray Users

GROUP 1 X-Ray Facility Manager and selected deputies.

GROUP 2 Faculty; Technicians; Research Workers; Degree by Thesis Students; Undergraduates; Project Students

GROUP 3 Undergraduates following undergraduate course teaching experiments

6.1.1 Information

Group 1 +2 Information concerning the safe operation of the equipment must be obtained either from the direct supervisor, or from an experienced research worker or experienced technician.
Radiation protection information is also given in this Local Rules document, a copy of which must be read by each user of the equipment.

Group 3 Undergraduates must receive safety information from the member of faculty in overall charge of their experimental programme.
This safety information must be included within the Experimental Schedule/Laboratory Script Document. Suggested information is given in Appendix C.
Further safety information may be given in the form of a lecture/video presentation by either the member of faculty (or his nominee) in charge of the experiment, or by the University Safety Service.

6.1.2 Instruction

Group 1+2 These users must receive clear instructions in the safe use of the X-ray

equipment. This should normally be provided by the supervisor but, where appropriate, may be given (by arrangement through the supervisor) either by an experienced research worker or an experienced technician. Written instructions must provide a safe system of work.
The form a system of work takes should follow advice given in Section 8 of these Local Rules supplemented, where necessary, by further written instructions or by reference to the manufacturer's operating manual. Users may only use X-ray equipment in the normal use conditions.

Group 3 Undergraduates must be given clear written instructions on the use of the equipment. These instructions must be provided in the Experimental Schedule/Laboratory Script documents. The instructions must make it clear that X-rays are hazardous and that under no circumstances may students expose themselves (or any other person) to the radiation.
They must be made aware of the distinction between **normal use** of an X-ray set, with the beam either within a local enclosure or totally enclosed, and the more potentially hazardous situation when access to the enclosure is required for lining-up operations. It must be made clear to undergraduates that they cannot undertake lining-up operations and may only use X-ray equipment in the normal use conditions. See Appendix C.

6.1.3 Training

Group 1+2 For this Group training should comprise:

(a) The information contained in this Local Rules document supplemented by:

(b) a lecture or video presentation from the University Safety Service or their nominee, and

(c) probably most important of all - 'on the job' training in the safe use of the equipment given either by the supervisor or by an experienced X-ray user.
On completion of (b) a licence is issued by the University Safety Service.

Group 3 Faculty who supervise undergraduate teaching experiments must ensure that the students receive any necessary training for work with X-ray equipment.
In general, training may take the form of information and instruction contained in the Laboratory Script documents.
For some work faculty may require undergraduates to receive additional lecture/video training from the University Safety Service or the School appointed radiation specialist. This extra training should not be necessary for undergraduates using the Telexometer or similar teaching X-ray sets.

6.1.4 Supervision

Group 1 No supervision required.

Group 2 This may come from two sources

(a) the **equipment** will be under the control of a **Nominated Person** who will

decide who may use the equipment, at what times and under which system of work, and

(b) supervision of the individual worker **must** be exercised by their supervisor, either directly or through a licensed, experienced X-ray equipment user.

Group 3 Undergraduates may only use **equipment** after permission has been obtained on their behalf (by their faculty supervisor) from the Nominated Person in charge of the equipment.
Supervision of the undergraduates' work will come either under the direct control of the responsible member of faculty or, where appropriate, under an experienced licensed technician or postgraduate demonstrator acting on behalf of the member of faculty.

6.2 The Ionising Radiations Regulations, 2017

These Regulations are aimed at minimising the exposure of persons to ionising radiation. Under the terms of the Regulations, **undergraduates** are regarded as employees and, hence, the relevant parts of Section 6.1 will apply to undergraduate students as indicated.

Control is to be achieved by keeping exposures as low as practicable, and by not exceeding the dose limits specified in Section 23. Control of exposure is to be achieved by Engineering Controls and Safe Systems of Work.

6.2.1 Code of Practice and Guidance Notes

The Health and Safety Executive have issued Guidance in their publication “Work with Ionising Radiation L121 ISBN 978-0-7176-17463-3”, giving more practical advice for users of X-ray equipment. The protection of persons against exposure to ionising radiation arising from any work activity is covered in “The Ionising Radiations Regulations 2017. A copy of this Code of Practice is available for consultation in the University Safety Service.

6.3 Provision and Use of Work Equipment Regulations 1998

The Provision and Use of Work Equipment Regulations 1998 (PUWER) came into force on5 December 1998. See local rules SSC-72-6.

7. ORGANISATION AND RESPONSIBILITIES

7.1 Organisation

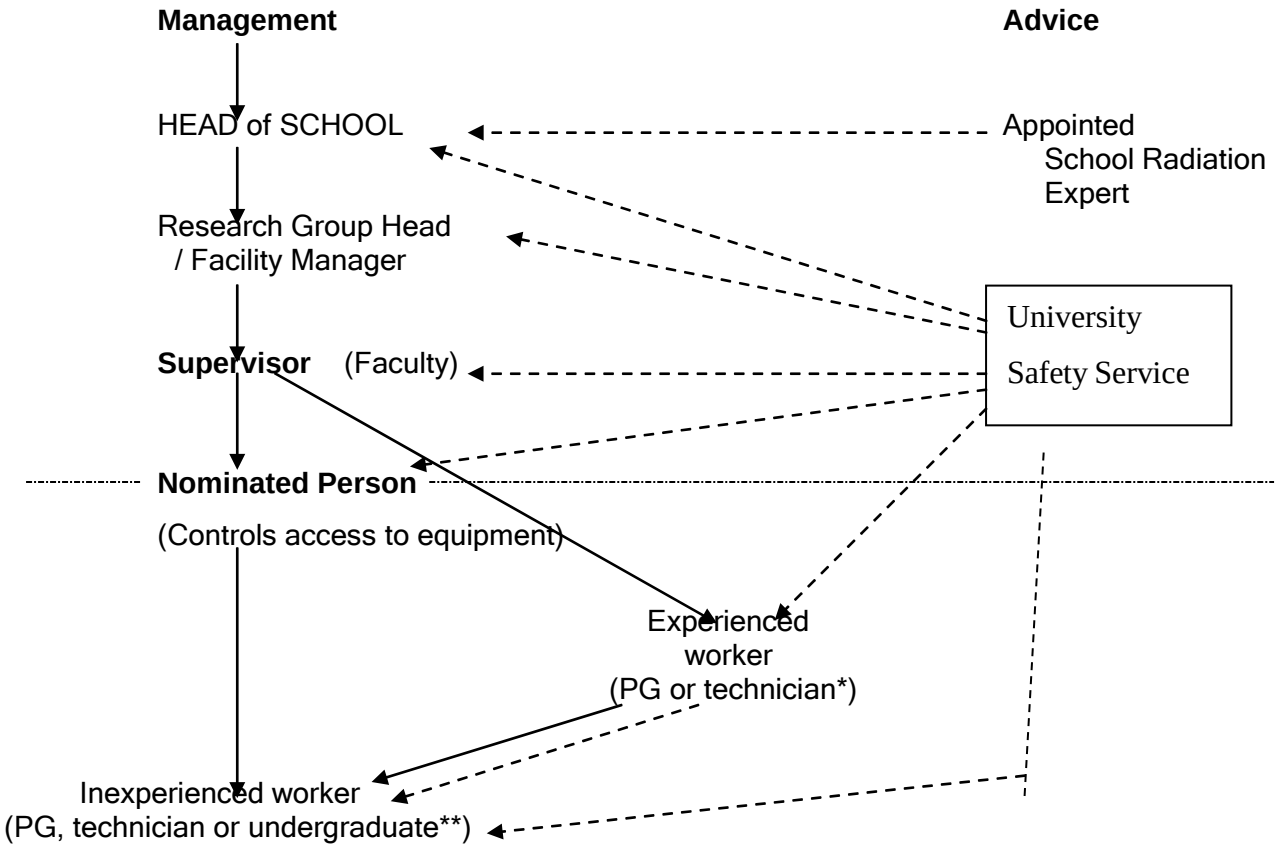
The organisation for the safe management of X-ray equipment is shown below.

7.2 Responsibilities

Management responsibilities for the control and use of X-ray equipment are outlined in the following diagram. Further information is given in Section 6.1 under the Requirements of the Health and Safety at Work Act.
Under the **Ionising Radiations Regulations**, in each Science School of the University, the Head of School has the dual responsibility for minimising radiation doses by ensuring the provision of effective engineering controls as part of the equipment, and for providing,

through the School management chain, safe systems of work.

USE OF X-RAY EQUIPMENT - SAFETY ORGANISATION



* May be required to instruct/supervise, but faculty member carries overall responsibility.

** Not permitted to 'Align beams or calibrate equipment'. Must only work in 'normal use' mode.

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8. LOCAL RULES FOR RADIATION PROTECTION

8.0 Summary of the Local Rules

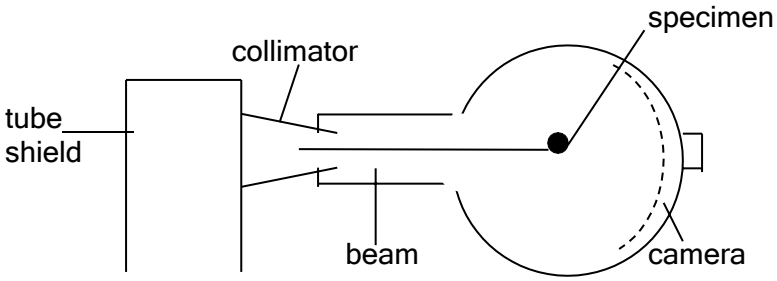
These are given on page 1.

8.1 Engineering Controls

8.1.1 Definition of 'normal use' condition

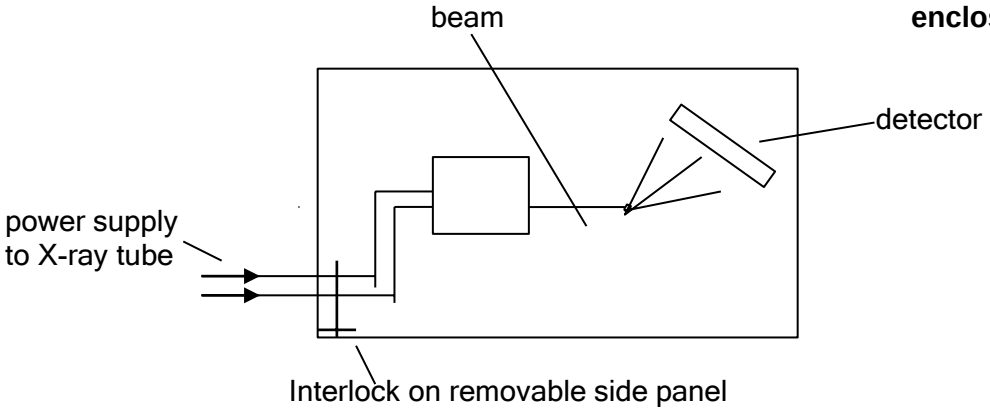
This condition exists when **either** the X-rays are contained within a **fully enclosed** tube shield collimator camera system, which may be termed a **'Local Enclosure'**- See **Figure 1**:

Vertical section



or where the X-ray beam is not contained locally but is allowed to emerge as an exposed beam within some form of interlocked **'total enclosure'** – see **Figure 2**:

Plan of total enclosure



8.1.2 Controls Engineering

8.1.2.1 Shielding

Local and total enclosures must be adequately shielded to < 5 μSv per hour at 8cm, i.e. 7-20 cps on Mini Monitor type 5.10X with GM tube ZP1481.

8.1.2.2 Effective devices

The HSE Ionising Radiations Regulations 2018 Code of Practice also requires the provision of **effective devices** which ensure that the beam cannot be produced, e.g. beam shutters cannot be opened unless the local shielding, or walls of the total enclosure are in place. The effective device must terminate the useful beam whenever any cover or barrier is removed. This is best achieved by 'lock on' shutters which mechanically lock the collimator camera system to the tube shield. Less effective, but acceptable, are automatic shutters which are usually electromagnetic devices which, when a camera/collimator system is removed, cause prompt closure of the shutter mechanism.

Whatever devices are provided as engineering controls must be difficult to override!!

Similarly camera collimators and shutters must fit together effectively to prevent leakage of radiation.

8.1.2.3 Automatic indications

It is vital that each X-ray set be provided with an 'X-rays on' warning sign to indicate that the X-ray tube is energised.

It is also essential that each set is equipped with automatic shutter status lamps:

red	= shutter open
green	= shutter closed

8.2 A Safe System of Work to Support the Engineering Controls

It is essential that users of X-ray equipment must assume that the engineering controls might fail.

All users, therefore, **must**, on arrival in the X-ray room, switch on the X-ray monitor and leave it switched on close to their working position, as long as they are in the room.

Users are required to use the monitor to check that they are not being exposed to >5 μSv per hour (7-20 cps on the Mini 5.10 X). Users are also required to make frequent checks with the monitor to make sure that X-rays (>5μSv per hour) are not leaking from enclosure tube shields, or from gaps between camera/collimator/tube shield components. If

excessive leakage or scattered radiation is detected the user should **immediately switch off the equipment** and seek advice from the Nominated Person or his representative, or the University Safety Service.

NB: Monitoring is especially important during lining up operations. (See Appendix B)

Users are reminded to monitor where they are likely to put their hands; to monitor eye-pieces **before** they use them and to monitor their working position.

Written safe systems of works for **undergraduates** must be provided in the Experimental Schedule/Laboratory Script document.

8.3 Administrative Controls for Use of X-Ray Equipment

8.3.1 Forward Planning and Structural Requirements

See the Introduction Section 1.2.

8.3.2 General Administrative Control Arrangements

8.3.2.1 Controlled Areas

To meet the requirements of the Ionising Radiations Regulations each X-ray enclosure has been designated a **CONTROLLED AREA.**

8.3.2.2 The Nominated Person

Each controlled area must be under the administrative control of a **NOMINATED PERSON.** The nominated person controls access to each controlled area, (i.e. the Nominated Person has overall control of the X-ray equipment.) He or she is **not** responsible for the **direct supervision** of workers who use the equipment, only for controlling access and oversight for the time they are operating the equipment. Responsibility for the safety of users rests with their supervisors who would normally be members of faculty or senior technical staff.

The Nominated Person has control over:

(a) who can use the equipment and when;
(b) where cameras or detectors may be located;
(c) whether a proposed safe system of work is accepted;
(d) the Nominated Person has direct control of any special tools available for overriding interlocks to undertake 'lining-up' operations;
(e) the Nominated Person must ensure that any enclosure where X-ray optics equipment is operated is **labelled** as a controlled area (labels are obtainable from University Safety Service.);
(f) the Nominated Person can only authorise X-ray equipment to be used if it is to be used in the **normal use condition**. There are no exceptions to this rule.

8.3.2.3 Safe Systems of Work

There are two distinct Safe Systems of Work:

First - the safe system termed **'Normal Use'.** This system, with the beam either fully enclosed or within an enclosure, is the 'preferred system'.

Persons who (with approval from the Nominated Person) can use X-ray optics equipment in the normal use mode are:

- persons who have obtained a full X-ray licence;
- project students who may be given a special restricted licence;
- undergraduate students who are undertaking X-ray experiments as part of their undergraduate course. See Section 6.1 for details of information, instruction, training and supervision required for undergraduate teaching experiments.

A completely different Safe System of Work termed a **'Permit to Work'** must be followed for maintenance or **lining-up operations** in which there may be access to the X-ray beam or scattered radiation.

8.3.3 Details of Permit to Work operations

8.3.3.1 Lining-Up Operations

Entry to the Controlled Area may only be undertaken by following the instructions provided in a written **Permit to Work.**

An outline example of a standard Permit to Work is given at Appendix A.

The only persons permitted to undertake lining-up operations are the Nominated Person, selected deputies or company service personnel.

Notes : (i) Once the lining-up operation is completed the equipment must be returned to the normal use condition.

(ii) During the lining-up operation, unless there is an effective 'beam stop' in which the beam is terminated, it may be necessary to make the whole of the X-ray room into a controlled area. In this case entry into the area must be restricted to licence holders authorised by the Nominated Person. A temporary warning notice, which may take the form of an illuminated sign, must be placed at the entrance to the temporary controlled area. The boundary of this area would normally be expected to be the walls of the particular laboratory. However, in the case of a large X-ray room, the boundary of the controlled area may be defined by barriers or local shielding. In either case, the area must be clearly labelled as a controlled area, with temporary controlled area warning signs, AND the radiation dose rate at the boundary of the temporary controlled area **must not exceed 5 µSv per hour.**

This dose rate must be checked by monitoring, or its value determined by a calculation checked by the University Safety Service or a nominated member of faculty who has the relevant experience.

Responsibility for supervision of each lining-up operation rests with the Nominated Person.

8.3.3.2 Repair, Modification or Maintenance

Faults on the equipment must be reported to the Nominated Person, who will arrange for any necessary repairs, modification or maintenance on the equipment.

Maintenance engineers must be told to report their presence to the Nominated Person for the piece of equipment to be worked on.

Each maintenance engineer must be issued with a permit to work certificate - an example of which is given at Appendix B.

9. DOSIMETRY

Since users will only use the X-Ray equipment in „normal" mode, there is no requirement for each user to have a personal dosemeter.

Licensed persons using monochromators or other procedures where the hands might be placed near an X-ray source must discuss their proposed work with the University Safety Service who might advise that they wear fingertip dosemeters.

The dosemeters, usually thermoluminescent dosemeters (TLDs) are normally issued for periods of three calendar months, and are used to verify that the dose restrictions required by the Ionising Radiations Regulations are being met.

Dosemeters are issued by the University Safety Service who also keeps the personal dose records of each X-ray worker.

10. MONITORING EQUIPMENT

Individual X-ray users are required by the Local Rules to carry out frequent checks of the X-ray monitors provided.

No work with the X-ray equipment is permitted unless a monitor is present and the following checks have been made:

- battery check - indicator needle to be beyond red line or well into the green segment;
- speaker to be switched on and steady 1-2 clicks per second to be audible.

CAUTION!!

When monitoring: switch on, do the above checks, and move probe slowly towards area where X-ray leakage is suspected.

If probe is placed in a very high dose rate region, and then switched on, the detector may

saturate and read zero!

Formal checking of monitors will be undertaken from time to time by the University Safety Service.

11. EMERGENCY PROCEDURES

Fire - Operate fire alarm.

- If entry is needed to extinguish fire, fire-fighters are advised to go to the mains isolator switch and switch this in the OFF position. They will then observe-that the X-rays on warning lamps are no longer illuminated. Persons entering the area need not worry about any risk from ionising radiation. They should, however, be aware that other electrical components might still be live. It is safest to use CO2 extinguishers on electrical equipment fires. If personal risk is foreseeable, the area should be evacuated and left for the attention of the fire service.

Injured persons If there has been an explosion or another serious accident giving rise to casualties within the X-ray room, first aiders are advised to turn off the electrical supply by operating the main isolator switch as described above.

12. GENERAL PRECAUTIONS WITH ALL X-RAY WORK

All X-ray users must, at all times, exercise great care when using X-ray equipment.

In particular, they are asked to be aware of the state of the equipment, e.g. are X-rays being generated, are shutters open or closed? and to be aware that faults can occur, e.g. shutters can jam open and microswitches may fail.

It is very, very important, therefore, to keep the radiation monitor switched on at all times, to keep it near your working position, and to frequently check the equipment for possible leakage of X-rays!

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APPENDIX A

EXAMPLE OF STANDARD 'LINING-UP' OPERATION

PERMIT TO WORK CERTIFICATE

Note (i) Only Licensed persons may undertake lining up operations.
(ii) Only persons with a full University of Sussex X-ray licence may undertake these operations and only then if the Nominated Person has given approval.

Generator manufacturer ……..…….. Type No ……..……

Location ……..……

Goniometer type ……..……

Detector type ……..……

Persons authorised by this Certificate: ……..…

…… Time

period for which this certificate is valid: from …… to ……..

Detailed procedure

1. Obtain approval from Nominated Person.
2. Obtain interlock override tool from Nominated Person.
3. Switch on and check radiation monitor.
4. Set up any shielding you may need to protect you from scattered radiation.
5. Keep voltage as low as is practicable; current as low as is practicable.
6. If necessary, use long handling device approved by Nominated Person to hold fluorescent material used to locate X-ray beam.
7. Make frequent checks with radiation monitor to ensure that you are not exposed to > 5μSv per hour. If necessary, use shielding.
8. After lining up replace side of enclosure, reset interlocks - use monitor to check that any radiation leakage from the enclosure does not exceed 5μSv per hour.

SPECIAL CONDITIONS

Work authorised by ……(Nominated Person in charge of set)

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APPENDIX B

PERMIT TO WORK CERTIFICATE FOR REPAIR, MODIFICATION OR MAINTENANCE WORK ON AN X-RAY SET

X-ray set identification number: ……..……

Location: ……..……

Generator manufacturer ……..… Type No…….……

Actions in event of fire ……..……..……
……

Actions to obtain first aid assistance ……..
……

Work Arrangements

(a) Report your presence in building to Nominated person or his representative.

(b) Seek approval to undertake work on the X-ray set from the Nominated Person or their representative.

(c) Collect key to X-ray room or X-ray enclosure.

Special Requirements

If the equipment needs to be left partially dismantled, then the engineer:

- must post a warning notice indicating that the equipment might be dangerous to use
- take away the fuses to prevent anyone attempting to use the equipment and leave a notice - 'CAUTION: work in progress on this X-ray set. Do not replace the fuses.'

NOTE: During servicing/maintenance, modification or repair of X-ray equipment, the engineer or technician in charge of the work is totally responsible for ensuring their own safety and the safety of other persons who might be affected by the work.

It is, therefore, advised that the Service Engineer or Technician controls access to the X-ray room using a key issued to him by the Nominated Person or his representative.

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APPENDIX C

BASIC RADIATION PROTECTION INFORMATION FOR UNDERGRADUATES

Ensure no part of person is placed in the beam - achieved by enclosure of beam.

Philosophy, radiation is easy to detect. It is low energy and easily stopped.

ALWAYS ensure MINI monitor is switched on and working all the time you are present. You will hear steady background ticking.

If a shutter fails or X-rays emerge - tick rate will increase significantly.

ALWAYS use MINI monitor to check that, where you are located, dose rate is less than 5μSv per hour (7 to 20 counts per second) and that radiation is not emerging from your camera or collimator system.

- Dosimetry - may provide evidence of exposure to X-rays.
- Undergraduate project students need dosimeters.
- Undergraduate students do not receive dosimeters for teaching experiments.

NOTE: ANY suspected exposure to X-rays must be reported.

IMPORTANT

Undergraduates must NEVER undertake lining-up operations (in which the beam may not be fully enclosed nor in an interlocked enclosure with the interlock defeated).

Undergraduate students MUST only work with X-ray set in the NORMAL USE CONDITION, i.e. where a member of faculty or senior technical staff has carried out the lining-up of beam, specimen, camera, etc. and where the beam is EITHER fully enclosed within the camera/collimator system OR is within an interlocked enclosure.

REMEMBER each X-ray set is under the charge of a NOMINATED PERSON - normally you must find out who this is and only use the equipment with his or her approval.

REMEMBER

1. Always MONITOR - never trust the equipment - be prepared for faults to occur. Concentrate on what you are doing and be alert to the state of the equipment.

2. Always work in the NORMAL USE condition, i.e. beam enclosed or apparatus within an enclosure.

3. **If in any doubt - ALWAYS ASK.**

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SUMMARY OF PRACTICAL PROTECTION

(a) **Enclosure** and shielding of equipment

(b) **Restriction of access** to unenclosed equipment

(c) Interlocks and **safety switches**

(d) **Warning signs -** 'X-rays on'; 'Shutter open'

(e) **Monitoring** - use monitor at all times 7-20 counts per second

(f) **Care during alignment** - undergraduates must not undertake lining up operations

(g) **Training and supervision** - each set is in the charge of a Nominated Person who controls access and use.

(h) **Dosimetry** – general users: no TLD required.

(i) **Maintenance** - report all faults

(j) **Awareness of state of the equipment** - interlocks or microswitches can fail, so use monitor to make frequent checks.

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