Risk Assessment Form
Chemistry Research Laboratory

Procedure	Use of X-ray diffractometers in the Inorganic Materials Characterisation Facility

Name(s) of person performing the work	User list kept up to date by facility manager. Use https://imc.web.ox.ac.uk/feedback-form-0 to request details.		
Name of Assessor	Simon Cassidy (facility manager)		
Date of Assessment		**Room Number**	CG1,CG8
Next Review due:			

Outline of procedure / activity and location: [Guidance Note 2]

Use of X-ray diffractometers for studying the structure of chemicals and inorganic materials. This risk assessment covers the use of:

- Malvern Panalytical Empyrean (Cu alpha 1) DY1266
- Panalytical Xpert (Cu alpha 1) DY1892
- Bruker Advance Eco (Cu alpha 1,2) SN 209499
- Malvern Panalytical Empyrean (Mo alpha 1,2 or Ag alpha 1,2) DY1360
- Rigaku Smartlab 3kW (Cu alpha 1,2) SRN 0001439
- Rigaku Synergy S (Cu,Mo alpha 1,2) PL203401102

This risk assessment ONLY covers work inside cabinets/enclosures which are closed and interlocked such that there is no access to the X-ray beam. Operations that involve defeating the instrument interlock system are not covered by this risk assessment. It also does not address risks during periodic maintenance carried out by the external agents under service contract.

Potential hazards [Guidance note 3-4]

Substance/Item of equipment/procedure or physical location	Known or Expected Hazards
Ionising radiation	**Introduction:** Regulation 8 of the Ionising Radiations Regulations 2017 (IRR17) requires the University to undertake a radiation risk assessment before commencing a new work activity involving ionising radiation. IRR17 and the Management of Health and Safety at Work Regulations (MHSWR) also require a review of existing risk assessments at appropriate intervals to ensure that they remain suitable and sufficient. In this regard, a radiation risk assessment shall be deemed *suitable and sufficient* if it addresses the requirements of Paragraph 70 and 71 of the IRR17 Approved Code of Practice. The contents of these paragraphs are covered in a manner specific to the instruments in question in the risk assessment below and the paragraphs are reproduced in Sections 1 and 2 of the appendix. This risk assessment considers equipment using Cu (8keV), Mo (17keV) and Ag (22keV) X-ray sources operating at a maximum of 60kV and with tube current up to 40 mA. There is often little or no filtration to harden the beam. Consequently, the equipment creates external radiation hazard from x-rays.. All tissues of the body are at risk from x-radiation but in the range of energy concerned a significant amount of energy would be deposited in the superficial tissues i.e. the skin and immediately underlying tissue and the eyes. The following covers the key hazards of working with ionising radiation: • Ionising radiations can cause dermatitis, burns, cell damage, cataracts and changes to blood. Exposure to ionising radiation can damage DNA and can cause health effects, such as cancer, later in life. All tissues of the body are at risk from x-radiation but in the range of energy concerned a significant amount of energy would be deposited in the superficial tissues i.e. the skin and immediately underlying tissue and the eyes. • Radiation dose rates in the collimated main beam can be of the order of tens of gray per minute, exposure to which can lead to overexposure of and in some cases serious injury to skin, immediately underlying tissues and eyes depending on absorbed dose and area irradiated. • Radiation dose rates in the uncollimated main beam can be of the order of tens of grays per second. Exposure to such a beam could result in very serious injury to the skin, immediately underlying tissues and the eyes.

	• Radiation dose rates due to unshielded scattered radiation can be of the order of tens of milligray per hour in close proximity to the x-ray output, which might not result in acute damage but can cause lasting damage to long-term health if accumulated. • Radiation not from the main beam or scatter is reduced by tube shielding. With a tube shield in place this radiation is very substantially shielded and is referred to as "tube shield leakage radiation". Shields are manufactured so that the dose received in an hour at 1 metre from the tube will not exceed 1 microgray. In practice, radiation levels around shielded tube heads (for example, unused tube ports) are much lower than this. Partial or total loss of shielding afforded by the tube shield will produce uncollimated x-ray beams having dose rates of the order of tens of grays per second. Exposure to such beams could result in very serious injury to the skin, underlying tissues and the eyes.
Electricity	• Electric shock is the effect produced on the body and particularly on the nervous system by an electrical current passing through it. The effect depends on the current strength which itself depends on the voltage and body resistance *i.e*. path length and surface resistance of skin (which is much reduced when wet). Death can be the result of the normal voltage of 240 V causing currents of greater than 30 mA to flow through the body for more than 40 ms. Minor shocks may also cause injury following involuntary muscle contraction. • Burns caused by the passage of heavy currents through the body or by direct contact with an electrically heated surface. • Explosion and fire caused by electrical sparks, short circuits or overload heating, old wiring in the presence of flammable material.
Motorised parts	▪ People can be struck and injured by moving parts of machinery or ejected material. Parts of the body can also be drawn in or trapped between rollers, belts and pulley drives ▪ Sharp edges can cause cuts and severing injuries, sharp-pointed parts can cause stabbing or puncture the skin, and rough surface parts can cause friction or abrasion
Sample Hazards	▪ Specific sample hazards vary by user and experiment. These are not covered in this risk assessment and hazardous samples should have their own risk assessment.

Control Measures:

These precautions are not meant to be exhaustive and all use should be in accordance with the Ionising Radiations Regulations 2017 (IRR17) and the department local rules.

Ionising radiation

The Diffractometers are cabinet-type equipment containing an otherwise open beam (i.e. the x-ray tube, sample and detector assembly are in open space within the cabinet). A purpose built and interlocked enclosure contains the x-ray beam such that access outside to significant radiation dose rates outside the cabinet during routine use are not significant; typically being less than 1 microsievert per hour. The various components of the barrier and shielding are interlocked so that their removal will terminate the production of x-rays or prevent it (by shutter mechanism). The X-ray set has visual warning signals that are activated automatically when X-rays are about to be emitted and remains on when X-rays are being emitted. Shutters also have warning lights which indicate automatically whether they are open or shut. The Synergy-S diffractometer has additional "beam stops" comprising shielding of sufficient thickness to terminate the main beam and prevent it passing into the workplace.

The purpose built and interlocked enclosures contain the x-ray beam such that access to significant radiation dose rates outside the cabinet during routine use are not significant; typically being less than 1 microsievert per hour. Interlocks on access panels terminate or shutter the beam if opened, preventing any potential exposure to the main beam. However, during beam diagnostics or maintenance, when interlocks may need to be overridden to work under open-beam conditions, dose rates of the order of those discussed in the hazards section will be accessible inside the compromised cabinet.

The University has previously provided radiation dosemeters to x-ray optics workers without their recording any significant exposures. With dose rates around the equipment not expected to exceed 1 microsievert per hour (in practice around cabinet equipment, dose rates will be much lower than this), significant received doses are not reasonably foreseeable during routine use. At a worst case whole body dose rate of 1 microsievert per hour, a worker would have to remain in position for 1000 hours before reaching the University's chosen investigation level of 1 mSv. This is not reasonably foreseeable. Dosemeters are not routinely supplied to x-ray optics users.

IRR17 regulation 9(6) requires employers to ensure that the foetus does not receive a dose of more than 1 millisievert during the remainder of the term after declaration of pregnancy. Paragraph 163 of the supporting guidance states that, for penetrating radiations, this is equivalent to an external dose of 2 millisieverts to the maternal abdomen. Dose rates measured in the operator's position of the University's diffractometers should not exceed 1 microsievert per hour (pessimistic figure chosen for the benefit of this calculation) meaning that a pregnant woman would have to remain in this position for 2000 hours before the foetus received a dose of 1 mSv. This is equivalent to an entire working year and is not therefore considered reasonably foreseeable. Over the course of the pregnancy, it is not conceivable that a pregnant worker could receive an abdomen dose of 2 millisieverts from use of the equipment. It is not therefore necessary to alter the working conditions of any pregnant workers.

There are no additional risks to nursing mothers from the operation of these instruments.

TLD dosemeters would be supplied to persons authorised to work under open beam conditions. However, in practice it is accepted that because of the collimated nature of the beam, the dosemeter is unlikely to record a dose in a foreseeable incident situation.

The equipment will be operated in accordance with the manufacturer's instructions. During routine operation no specific information on exposure restriction is required, other than not to attempt to defeat interlocks or remove shielding. Beam diagnostics and beam alignment work by authorised persons must be in accordance with manufacturer's instructions. In accordance with the requirements of UPS1/12, local training must be provided by the Department on open beam procedures will be based on manufacturer's instruction.

Equipment will be operated in accordance with manufacturer's instructions and local rules will be prepared. Work is conducted in accordance with the requirements of the University Radiation Safety Policy Statement (UPS 1/12: Management of Work with Ionising Radiation at the University of Oxford).

It is not expected that the interlocks will need to be overridden for the operation or maintenance of these instruments. Should this need to happen, then the local rules must contain written arrangements for authorised work and a separate risk assessment for the specific open beam work should be written and approved by the URPO.

Failure in routine work of segregation barrier interlocks or other interlocks could result in enhanced exposure to scattered radiation and tube shield leakage radiation; and to very serious overexposure to main beam radiation. Loss of beam stop arrangements could result in very serious overexposure to main beam radiation. Monthly checks will be made and recorded of the function of the safety critical warning lights, interlocks and emergency stop devices, dose rate measurements will be recorded of any leakage through the cabinet or shutter: all in accordance with procedures described in the local rules. Any deficiencies will be reported to the Senior RPS and the equipment taken out of operation until the service company has carried out necessary remedial work. Annual service by a qualified service company is recommended.

For routine maintenance, the equipment will be formally handed over to service company who will operate in accordance with their own risk assessments and method statements/local rules. The Department will seek confirmation in advance of servicing (and particularly significant maintenance) that these documents exist. The documents should outline the steps taken by the service company to safeguard their own health and safety whilst on site, and also the health and safety of all persons within the Department. At the end of scheduled maintenance, the service company must provide a written statement that the equipment has been left in a safe operational state i.e. that all safety features and warning devices are operational and that there is sufficient protection of persons from exposure to ionising radiation (that all the shielding is in place).

Electrical hazards

Laboratory supply of mains electricity to the instrument is *via* a 3-phase 415 V, 50 Hz socket. Ancillary office computers are 240 V, 50 Hz. The diffractometer generator operates at 45kV and 40mA, and is cooled by an external water chiller circuit.

- Plugs that are cracked or broken must not be used. The plugs must be wired properly, the conductors securely fixed and the cable firmly held by the strain relief grip.
- Replacing any fuses inside the instrument should be carried out by a qualified service engineer or under their advice. Electronic Workshop personnel will advise in case of doubt.
- All cables must be in good condition and free from breaks in the insulation. Cables must be sufficiently robust to withstand the wear and tear and fully waterproof where water may come within the vicinity of the apparatus.
- The diffractometer has external water cooling. Should a leak appear the instrument should be turned off via the emergency stop immediately and the water flow stopped as soon as it is safe to do so.
- Care should be taken to ensure that any cabling inside the instrument cabinet is not strained, pulled, crushed, cut or distorted by the moving parts of the diffractometer.
- Cables must not be run across the floor in such a way as to cause a tripping hazard or to be susceptible to damage from passing traffic. If it is necessary to run cables across walkways, they must be covered with cable protectors.
- The diffractometer must not be used in the vicinity of flammable or explosive gases. Ordinary electrical equipment is a possible source of ignition.
- The location of the emergency stop button, and the power off procedure must be clear and known so that power can be turned off rapidly in an emergency.

Motorised parts

The instrument is also configured such that the door is required to be closed and locked before the motorised parts of the instrument are enabled. This configuration should not be interfered with.

Sample Hazards

- Additional hazards may arise from the users' samples. All samples that are used on the instrument should be safe to handle and not require additional PPE such as disposable gloves.
- All users should be advised in safe handling and preparation of samples and sample holders. All powders must be secure and should not spill from the mounted position on the sample holder.
- All samples measured in the diffractometer should be recorded in a log book.
- If a sample could be hazardous towards any members of the user group during normal operation then a separate risk assessment for the sample should be carried out and a notice of its use should be placed on the diffractometer advising not to handle the sample or operate the diffractometer until that

sample has been cleared.

Users and Access

The relevant University radiation safety policy supplement (UPS1/12) details responsibilities of Heads of Department for implementing appropriate organisational arrangements within their departments to manage radiation safety. The supplement also specifies the measures required to comply with legislative requirements. Heads of Department are responsible for compliance with the University safety policies. As part of that responsibility, Heads of Department are required to appoint Radiation Protection Supervisors (RPS) to assist them to achieve compliance with legislative requirements and University policies.

The equipment should only be used by registered radiation workers who have been individually authorised and trained in its operation by the responsible RPS. All radiation workers receive radiation safety training from the Safety Office before undertaking work. Users should be made fully aware of the risks and safety features of the instrument and its surrounding environment as set out in this document.

Appropriate signage should be outside the instrument room to indicate that ionising radiation is present. A 'ionising radiation – emergencies' notice sheet should be in place to notify users of the RPS and SRPS responsible for the instrument. Access to the room should be restricted to only trained users if possible. Appropriate notices to prevent unauthorised use should be in place if this is not possible. Non-users should be made aware not to approach or try to use the X-ray diffractometers if they need to be given access to the instrument room for other purposes.

No attempt should be made to defeat any of the equipment's installed safety features. Any damage to the equipment or suspected failure of a safety feature must be reported to the RPS and SPRS, and the instrument must be taken out of service immediately until such time that it can be assessed by a service engineer.

The equipment must be maintained in accordance with manufacturer instructions. User maintenance on the instrument should be carried out as frequently as advised by the manufacturer's instructions and users may be trained to carry out basic maintenance when there are no additional risks involved beyond those of standard operation. If the instrument is out of service for over a year or beyond its next due service, then it should be serviced by a qualified engineer before being put back into use.

Persons potentially at risk: [Guidance note 5]

X-ray exposure: Radiological risks arising out of routine experimental work are not considered to be significant. Estimates of annual doses for different categories of worker are:

(i) Employees who work with ionising radiation: A few microsieverts per month.

(ii) Foetuses of employees who work with ionising radiation: A few microsieverts per month. Not foreseeable that foetal doses could approach anywhere near 1 mSv

during term of pregnancy.

(iii) Breastfeeding infants of employees who work with ionising radiation: Not applicable.

(iv) Other employees: Negligible dose.

(v) Foetuses of other employees: Negligible dose.

(vi) Breastfeeding infants of other employees: Not applicable.

(vii) Other persons on University premises: Negligible dose.

(viii) Other persons off University premises: No exposure.

Electric Shock: most likely the user themselves. Risks arising out of routine experimental work are not considered to be significant. Work involving increased risk of electrical exposure should be conducted by a qualified engineer under a separate risk assessment.

Mechanical collision: most likely the user themselves. Risks arising out of routine experimental work are not considered to be significant.

Fire and Explosion: injuries may be widespread. Risks arising out of routine experimental work are not considered to be significant.

Action in event of an accident or emergency: [Guidance note 6]

X-ray exposure

- **RPS, SPRS and URPO should be notified. Instrument should be powered off and the ignition key removed.**

Electric Shock

- **Power must be switched off before touching the injured person.**

Fire

- **The standard fire procedures must be followed. Water must never be used on an electrical fire.**

Level of risk remaining

Following the precautions outline above, the risk remaining should be minimal.

Training Requirements

Hands-on training in the safe use of the diffractometer should be given by the RPS responsible for the instrument. All trainees must know and be known to the RPS, appropriate logs of users must be kept up to date.

Review of the Risk Assessment: [Guidance note 8]

Date of review		Name of reviewer	
Date of next review		Signature	

Have the control measures been effective in controlling the risk?

Yes	No

Have there been any changes in the procedure or in the information available which affect the estimated level of risk from the listed substances

Yes	No

What changes to the control measures are required?

APPENDIX

1. MATTERS TO BE CONSIDERED IN A RADIATION RISK ASSESSMENT

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

The x-ray generators used in x-ray optics typically operate up to around 100kV and with tube current up to 50 mA. There is often little or no filtration to harden the beam. Consequently, the equipment creates external radiation hazard from x-rays with energies up to around 100 keV. All tissues of the body are at risk from x-radiation but in the range of energy concerned a significant amount of energy would be deposited in the superficial tissues i.e. the skin and immediately underlying tissue and the eyes.

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

For the purposes of radiation protection the x-ray output of a tube can be divided into three components as follows.

(i) ***Main beam radiation:*** Radiation dose rates in the *collimated* main beam can be of the order of tens of gray per *minute*, exposure to which can lead to overexposure of and in some cases serious injury to skin, immediately underlying tissues and eyes depending on absorbed dose and area irradiated. For example, doses high enough to cause radiation burns can be received in seconds. Such exposures will be localised rather than whole body exposures.

(ii) Radiation dose rates in the *uncollimated* main beam can be of the order of tens of grays per *second.* Exposure to such a beam could result in very serious injury to the skin, immediately underlying tissues and the eyes.

(iii) ***Scattered radiation:*** Radiation dose rates due to *unshielded* scattered radiation can be of the order of tens of milligray per *hour* in close proximity to the x-ray output.

(iv) ***Radiation emitted from tube other than in main beam:*** With a tube shield in place this radiation is very substantially shielded and is referred to as "tube shield leakage radiation". Shields are manufactured so that the dose received in an hour at 1 metre from the tube will not exceed 1 microgray. In practice, radiation levels around shielded tube heads (for example, unused tube ports) are much lower than this.

Partial or total loss of shielding afforded by the tube shield will produce uncollimated x-ray beams having dose rates of the order of tens of grays per *second.* Exposure to such beams could result in very serious injury to the skin, underlying tissues and the eyes.

X-ray diffraction equipment used at the University comes in three main designs:

A. ***Cabinet-type equipment containing an otherwise open beam (i.e. the x-ray tube, sample and detector assembly are in open space within the cabinet):*** A purpose built and interlocked enclosure contain the x-ray beam such that access outside to significant radiation dose rates outside the cabinet during routine use are not significant; typically being less than 1 microsievert per hour. Interlocks on access panels terminate or shutter the beam if opened, preventing any potential exposure to the main beam. However, during beam diagnostics or maintenance, when interlocks may need to be overridden to work under open-beam conditions, dose rates of the order of those discussed in (i) to (iii) above will be

accessible inside the compromised cabinet.

B. ***Cabinet-type equipment containing an entirely closed system:*** In certain cases, even within the cabinet, all optical components are enclosed such that accessible dose rates are not significant during routine use; typically being less than 1 microsievert per hour. Again however, open beam maintenance work may need to be carried out and dose rates of the order of those discussed in (i) to (iii) above will be accessible.

C. ***Enclosed optical equipment without cabinet:*** In these cases, typically the x-ray column has four functional ports which can feed separate experiments. All optical components are enclosed such that accessible dose rates are not significant during routine use; typically being less than 1 microsievert per hour. Again however, open beam maintenance work may need to be carried out and dose rates of the order of those discussed in (i) to (iii) above will be accessible.

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

Not relevant.

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

The University has previously provided radiation dosemeters to x-ray optics workers without their recording any significant exposures. With dose rates around the equipment not expected to exceed 1 microsievert per hour (in practice around cabinet equipment, dose rates will be much lower than this), significant received doses are not reasonably foreseeable during routine use.

At a worst case whole body dose rate of 1 microsievert per hour, a worker would have to remain in position for 1000 hours before reaching the University's chosen investigation level of 1 mSv. This is not reasonably foreseeable. Dosemeters are not routinely supplied to x-ray optics users.

TLD dosemeters are supplied to persons authorised to work under open beam conditions. However, in practice it is accepted that because of the collimated nature of the beam, the dosemeter is unlikely to record a dose in a foreseeable incident situation.

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

The equipment will be operated in accordance with the manufacturer's instructions. During routine operation no specific information on exposure restriction is required, other than not to attempt to defeat interlocks or remove shielding. Beam diagnostics and beam alignment work by authorised persons must be in accordance with manufacturer's instructions. In accordance with the requirements of UPS1/12, local training must be provided by the Department on open beam procedures will be based on manufacturer's instruction.

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

X-ray optics sets have a main beam enclosed in a structure which provides a physical barrier between the beam and persons. The barrier may also provide or incorporate shielding from scattered radiation. It may also ensure that dose rates due to scattered radiation are at an acceptable level by maintaining sufficient distance between persons and the sources of main beam scatter.

The various components of the barrier and shielding are interlocked so that their removal will terminate the production of x-rays or prevent it (by shutter mechanism). Other components such as collimators may also be interlocked.

Sets have "beam stops" comprising shielding of sufficient thickness to terminate the main beam and prevent it passing into the workplace. In some systems a functional accessory acts as beam stop; or a part of the segregation barrier acts as beam stop; or the beam stop consists of a distinct structure positioned at the end of the beam path.

Sets have visual warning signals that are activated automatically when X-rays are about to be emitted and remains on when X-rays are being emitted. Shutters also have warning lights which indicate automatically whether they are open or shut.

During x-ray beam alignment, to gain access to the open beam, requires safety interlock devices to be defeated. Controls are in place to prevent interlocks being defeated by unauthorised people: for example; interlocks which can only be defeated by key, with a robust system of key control. Automatic warning lights should be fitted which are illuminated when interlocks are defeated.

Recommendation: Features specific to equipment should be addressed in the Department's own risk assessments.

(g) ***Any planned systems of work***

Equipment will be operated in accordance with manufacturer's instructions and local rules will be prepared. Work is conducted in accordance with the requirements of the University Radiation Safety Policy Statement (UPS 1/12: *Management of Work with Ionising Radiation at the University of Oxford*).

The local rules must contain written arrangements for authorised beam alignment work; including designation of a controlled area during the work and restriction of access by unauthorised people using barriers and signs (as appropriate). In the first place, the interlock override key should only be issued as part of a Permit to Work. The written arrangements include the use of a radiation monitor to confirm that access to dose rates in excess of 7.5 microsieverts per hour is prevented.

Recommendation: Departments must prepare their own risk assessment for the specific open beam work they undertake. This assessment must be approved by URPO.

Departmental local rules contain the requirements for routine monitoring of dose rates and functional testing of inherent safety features and warning devices.

For routine maintenance, the equipment will be formally handed over to service company who will operate in accordance with their own risk assessments and method statements/local rules. The Department will seek confirmation in advance of servicing (and particularly significant maintenance) that these documents exist. The documents should outline the steps taken by the service company to safeguard their own health and safety whilst on site, and also the health and safety of all persons within the Department. At the end of scheduled maintenance, the service company must provide a written statement that the equipment has been left in a safe operational state i.e. that all safety features and warning devices are operational and that there is sufficient protection of persons from exposure to ionising radiation (that all the shielding is in place).

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

Not applicable to x-ray work.

(i) ***The effectiveness and the suitability of personal protective equipment to be provided***

Not applicable. Radiation dose rates around the equipment do not warrant the adoption of personal protective equipment such as the use of lead aprons. During beam alignment work, lead aprons are likely to prove cumbersome and tiring, potentially compromising the user from safely undertaking the

operation.

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

As previously stated, dose rates around the equipment are reduced so far as reasonably practicable by the equipment's inherent safety features. Main risk of exposure exist during maintenance or beam alignment work with open beams. In these cases, the local rules require the establishing of appropriate controlled areas to prevent access to any area where the instantaneous dose rates exceeds 7.5 microsievert per hour.

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

See appendix to this risk assessment.

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

IN ROUTINE WORK

Failure of engineering controls, warning signal and special design features in routine work: Failure in routine work of segregation barrier interlocks or other interlocks (Note: interlocks should fail to safety) could result in enhanced exposure to scattered radiation and tube shield leakage radiation; and to very serious overexposure to main beam radiation. Loss of beam stop arrangements could result in very serious overexposure to main beam radiation.

Failure to follow specific x-ray diffraction local rules and UPS1/12 in routine work: Could result in increased exposure. For example, in the absence of radiation monitoring, any physical changes to the segregation barrier, associated shielding, beam stop and collimation arrangements might not be detected. This could result in increased exposure to scattered, main beam or tube shield leakage radiation. Additionally, the absence of testing schedules for safety devices and the absence of servicing, maintenance and testing could result in increased exposure.

WORK PERFORMED UNDER A PERMIT TO WORK

Failure of engineering controls, warning signals and special design features in work performed under a Permit to Work: When working under a Permit to Work, failure of interlocks could result in very serious overexposure to main beam radiation. With the segregation barrier absent, the absence or failure of collimators, shutters, beam stop and automatic warning signals could result in very serious overexposure to main beam radiation as well as enhanced exposure to scattered radiation. In the absence of the segregation barrier these components assume even greater importance in protection of the worker.

Failure to follow specific x-ray diffraction local rules and UPS1/12 in relation to Permits to Work: Could lead to very serious overexposure to main beam radiation as well as enhanced exposure to scattered radiation.

Failure to follow requirements of Permit to Work: Failure to follow the requirements contained in a Permit to Work could lead to very serious overexposure to main beam radiation as well as enhanced exposure to scattered radiation.

Recommendation: Departments must identify all reasonably foreseeable failure modes in their own risk assessment.

(m) ***Steps to prevent accidents or limit their consequences***

Contingency plans for reasonably foreseeable accidents and incidents are included in specific x-ray optics local rules.

All radiation workers receive radiation safety training from the Safety Office before undertaking work. In addition, departments are required to provide training in departmental procedures and any task-specific safety training.

Authorisation to work on open beam requires users to have received training in appropriate procedures by the equipment suppliers/agents or by a suitably qualified and experienced member of University staff.

Recommendation: Departments must identify all reasonably foreseeable failure modes in their own risk assessment.

2. MATTERS TO BE DETERMINED AS A RESULT OF THE RISK ASSESSMENT

(a) *What action is needed to ensure that the radiation exposure of all persons is kept as low as reasonably practicable (Reg 9(1))*

During routine use of the x-ray equipment in accordance with manufacturer's instructions, significant exposures are not reasonably foreseeable. Consequently, the "actions" to achieve ALARP are simply to follow those instructions and make no attempt to defeat any safety features.

During open beam work, significant exposures are reasonably foreseeable if optimised radiation safety measures contained within the permit to work are not adopted.

Local rules must be prepared in consultation with the URPO detailing the necessary safety measures during routine experimental use and open beam work.

Recommendation: Departments must ensure that local rules are prepared for x-ray optics work and implemented, including any procedures specific to the equipment.

(b) *What steps are necessary to achieve this control by the use of engineering controls, design features, safety devices and warning devices (Reg 9(2)(a)) and, in addition, by the development of systems of work (Reg 9(2)(b)).*

Engineering controls, safety features and warning devices inherent to the design of the equipment. Local rules require departments to restrict access during work with interlocks defeated using appropriate barriers and signs. Systems of work are recorded in the local rules.

(c) *Whether it is appropriate to provide personal protective equipment and if so what type would be adequate and suitable (Reg 9(2)(c))*

Not appropriate. See 2(i) above.

(d) *Whether it is appropriate to establish any dose constraints for planning or design purposes, and if so what values should be used (Reg 9(4))*

Not appropriate. Equipment is purchased *off the shelf* and was not subject to a specific University facility design.

Dose constraints (as a concept for designing procedures based around a maximum acceptable projected dose) are relevant for beam alignment work. However, in practice, due to the collimated

nature of the beam, significant exposures are not foreseeable unless the body passes through the beam. This is not acceptable and therefore the dose constraint for planning open beam procedures must always be zero. Dose constraints are not applicable to accidents and incidents.

(e) ***The need to alter the working conditions of any female employee who declares she is pregnant or breastfeeding (Reg 9(6))***

IRR17 regulation 9(6) requires employers to ensure that the foetus does not receive a dose of more than 1 millisievert during the remainder of the term after declaration of pregnancy. Paragraph 163 of the supporting guidance states that, for penetrating radiations, this is equivalent to an external dose of 2 millisieverts to the maternal abdomen. Dose rates measured in the operator's position of the University's diffractometers should not exceed 1 microsievert per hour (pessimistic figure chosen for the benefit of this calculation) meaning that a pregnant woman would have to remain in this position for 2000 hours before the foetus received a dose of 1 mSv. This is equivalent to an entire working year and is not therefore considered reasonably foreseeable. Over the course of the pregnancy, it is not conceivable that a pregnant worker could receive an abdomen dose of 2 millisieverts from use of the equipment. It is not therefore necessary to alter the working conditions of any pregnant workers.

During open beam work, risks are considered low but nonetheless in the event of any abdominal access to an errant beam, doses of the order of 2 mSv are foreseeable. However, use of the radiation monitor around the equipment at the start of the work (as per the local rules) will confirm that dose rates in the operator's position are acceptable. Nonetheless, it would be prudent that open beam work should not be undertaken when pregnant.

There are no risks to nursing mothers from radioactive contamination.

(f) ***An appropriate investigation level to check that exposures are being restricted so far as reasonably practicable (Reg 9(8))***

Regulation 9(8) requires employers to set an appropriate investigation level for different types of work with ionising radiation. The purpose of a dose investigation level is to enable employers to monitor whether radiation exposures are being restricted to a level which is as low as reasonably practicable [ALARP]. They should be set at levels of dose which, if exceeded by an individual, would prompt the radiation employer to carry out an investigation to determine whether doses are in fact ALARP or whether more needs to be done to further restrict exposures. The investigation level should be appropriate to the work being undertaken i.e. reflect a dose which you would not expect individuals to exceed when undertaking a particular task well.

The University has set an generic investigation level of 1 millisievert. This level of dose is appropriate for x-ray optics and there is little benefit of selecting a lower figure.

Having set appropriate investigation levels, employers are required establish procedures enabling you to identify when the investigation level has been exceeded and how it will be investigated. However, the University does not routinely issue x-ray optics users with a personal dosemeter (see 2(d) above) and therefore this cannot be used as a means of checking whether the investigation level has been exceeded.

However, as discussed in 3(e) above, dose rates measured in the operator's position of the University's equipment should not exceed 1 microsievert per hour. A worker will only exceed the dose investigation level if they were to remain in that position for over 1000 hours i.e. approximately 50% of the time. This is not reasonably foreseeable. As an alternative to policing compliance with the investigation level, Departments could monitor the hours of use of the equipment by individual if considered necessary.

(g) ***What maintenance and testing schedules are required for the control measures selected (Reg 11*****)**

Monthly checks will be made and recorded of the function of the safety critical warning lights, interlocks and emergency stop devices. Any deficiencies will be reported to the Senior RPS and the equipment taken out of operation until the service company has carried out necessary remedial work.

Since demonstration of compliance in certain areas (e.g. 3(e)&(f) above) depends on consistently low radiation levels in the irradiator room, dose rate measurements will be made and recorded at monthly intervals around the equipment. Any significant increase in dose rate will be brought to the attention of the URPO and service company and investigated.

Recommendation: Departments must identify and establish appropriate maintenance and testing schedules for equipment

(h) ***What contingency plans are necessary to address reasonably foreseeable accidents (Reg 13)***

Contingency plans are contained in departmental local rules for the following reasonably foreseeable incidents:

1. Equipment faults/failures
2. Personal exposures
3. Fire in the building
4. Breakdown of administrative controls

(i) ***The training needs of classified and non-classified employees (Reg 15)***

No employees will be designated as classified specifically for x-ray optics work. Individuals may occasionally be classified for other work with ionising radiation carried out at or outside the University, but the training needs for x-ray optics users will not differ whether they are classified or not.

The installers will provide information, instruction and training in the safe operation of the irradiator on completion of an installation or modifications. Departments will then identify suitably qualified and experienced individuals (typically the RPS) to disseminate this to new users.

Refresher training will be provided at appropriate intervals, taking account of the frequency of use of the equipment and the complexity of operation.

Recommendation: Departments must address the specific training needs of workers in their own risk assessments.

(j) ***The need to designate specific areas as controlled or supervised areas and to specify local rules (Regs 17 and 18)***

Whole body dose rates around the equipment during routine use do not typically exceed 1 microsievert per hour and it is not foreseeable that individuals could receive effective doses in excess of 6 millisieverts per year [IRR17 ACoP paragraph 297(a)&(e)]. Therefore, designation of *controlled areas* are not required.

During open beam work, interlocks are defeated or panels removed leaving the equipment in a state of reduced safety integrity. Dose rates above 7.5 microsieverts per hour are accessible in those circumstances and special procedures are required to restrict significant exposures. Consequently, the local rules require designation of *controlled areas* during such work.

(k) ***The actions needed to ensure restriction of access and other specific measures in controlled and supervised areas (Reg 19)***

Departmental local rules specify access restriction requirements for controlled areas.

(l) ***The need to designate certain employees as classified persons (Reg 21)***

Whilst controlled areas are designated, effective doses above 6 millisieverts per year and extremity exposures above 150 mSv per year are not reasonably foreseeable when working in accordance with risk-based procedures and manufacturer's instructions. Therefore, designation of classified persons is not considered necessary.

(m) ***The content of a suitable programme of dose assessment for employees designated as classified persons and for others who enter controlled areas (Regs 19 and 22)***

Not applicable. See 2(d), 3(e) and 3(l) above.

(n) ***The requirements for the leakage testing of radioactive sources (Reg 28)***

Not applicable.

(o) ***The responsibilities of managers for ensuring compliance with [IRR17]***

The relevant University radiation safety policy supplement (UPS1/12) details responsibilities of Heads of Department for implementing appropriate organisational arrangements within their departments to manage radiation safety. The supplement also specifies the measures required to comply with legislative requirements. Heads of Department are responsible for compliance with the University safety policies. As part of that responsibility, Heads of Department are required to appoint Radiation Protection Supervisors to assist them to achieve compliance with legislative requirements and University policies.

(p) ***An appropriate programme of monitoring or auditing of arrangements to check that the requirements of [IRR17] are being met***

Departments should implement their own internal monitoring and auditing arrangements to ensure compliance. DSOs and ASOs also have a role to play in checking compliance with University and legislative requirements. The Safety Office (URPO) will also undertake periodic audits of radiation safety arrangements within the Department.