The Society for Radiological Protection

Guidance on the safe use of handheld XRF analysers

Image supplied courtesy of Olympus

This guidance has been prepared by the SRP Non-Nuclear Industry Sectorial Committee. It is aimed at employers and other individuals who are responsible for the operation of hand held XRF equipment for chemical composition analysis. It provides users with guidance on radiation safety and the requirements of the relevant UK health and safety legislation.

The Society acknowledges the support of the Non-Nuclear Industry Sectorial Committee members, Health Protection Agency and the Health and Safety Executive in producing this guidance.

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1. Introduction and scope

Over recent years, handheld X-ray fluorescence spectrometry equipment has become increasingly popular for "in field" analysis of a wide range of materials in alloy analysis, scrap metal dealing, archaeology, the precious metals industry and even the toy industry.

Originally, portable XRF units utilised a sealed radioactive source, but these have been replaced with battery-powered x-ray generators. Such X-ray equipment is capable of producing high levels of radiation and this guidance has been produced to identify the potential risks and the appropriate safety requirements to ensure safe use.

This guidance is aimed at handheld XRF units utilising an X-ray generator, although many of the regulatory requirements and the protection principles described here will also apply to analysers utilising sealed radioactive sources.

2. The X-ray source

There are a number of X-ray fluorescence analysers (XRF) available on the market but they all function in a similar manner. Some of the UK suppliers are Bruker Ltd , Thermo-Scientific Niton, Olympus Innov-X Systems and Oxford Instruments. All suppliers (including hirers) must provide adequate health and safety information, but SRP recognise that this is not always adequate in relation to some second-hand equipment and equipment purchased from overseas, via the Internet.

The equipment contains a battery-powered X-ray tube, which emits a radiation beam (the "main beam") in a forward direction. The radiation levels are most intense at the beam aperture at the front end of the equipment and reduce in intensity with increasing distance. If unshielded the radiation in the main beam can be measured several metres from the equipment.

In terms of technical details, the x-ray tubes operate typically in the range 30-50 kV and up to ~55 μA and the beam angle is up to 45˚ above the horizontal. The exposure time varies depending on the material being analysed but is typically less than one minute. For analysis of small components an enclosed, interlocked test stand can be provided by the manufacturer.

Brüker S1 Turbo

with desk top stand

(Image courtesy of Brüker)

Innov-X Delta with desk top stand

(Image courtesy of Olympus)

When X-rays strike a material some are absorbed and some are scattered back in a different direction. Consequently, when the unit is in use (i.e. analysing a sample of material), scattered radiation can also be measured outside of the main beam. (See appendix 1.)

3. What are the radiation risks?

If handheld devices are used properly (e.g. see diagram A below), the radiation risks to operators and other persons should be minimal.

However, if the equipment is incorrectly set-up or misused there is the potential for unacceptable high radiation exposures. A radiation employer must ensure restriction of exposures by means of engineering controls and design features, by the provision and use of safety features and warning devices and by the provision of safe systems of work. Advice on these matters must be sought from a suitable Radiation Protection Adviser (see also appendix 2).

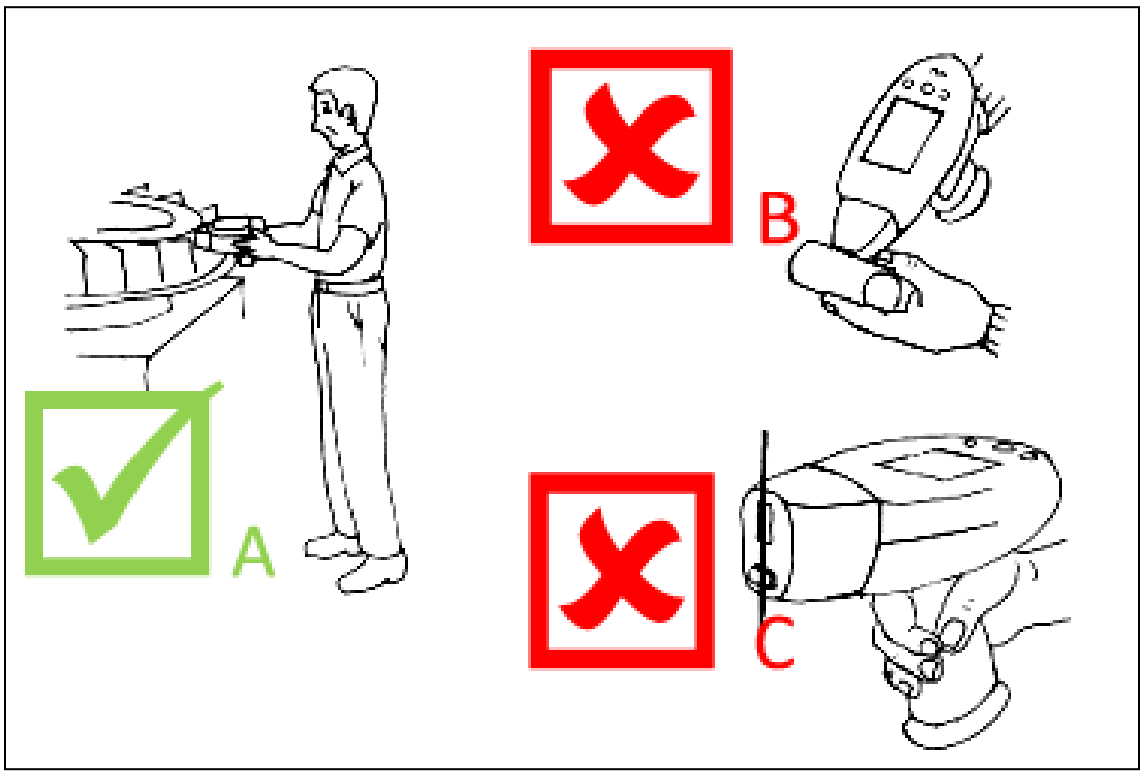
Photograph courtesy of Brüker

The following do not meet the requirements of UK radiation safety regulations:

- Devices without a proximity or low-count (backscatter) interlock.
- Devices with no clear indication of when X-rays are "on".
- Devices that can emit X-rays when the trigger is not held in the "on" position.

- Using a device for analysing small items without a suitable stand and enclosure.

If someone chose to override the proximity interlock or operate without fully covering the X-ray aperture (diagrams B and C) they could sustain a significant radiation dose: at the at the aperture dose rates can exceed 1 Sv/h and at 50 cm may exceed 1 mSv/h. Consequently, it would be possible to exceed the annual dose limit for the skin with a cumulative exposure of 30 minutes.



A - Two handed operation preventing temptation to place hand in front of instrument

B - Incorrect - Work piece should be held in a jig

C - Incorrect - Work piece should cover target area

4. Regulatory Requirements

Employers using this type of equipment must comply with the requirements of the **Ionising Radiations Regulations 1999** (IRR99). IRR99 and the supporting Approved Code of Practice "Work with ionising radiation", L121, are available on the HSE website: http://www.hse.gov.uk/pubns/priced/l121.pdf .

Manufacturers/suppliers must provide the employer with information about the proper use, testing and maintenance of the analyser. Information on nature and magnitude of the radiation risk and an overview of the regulatory requirements should also be provided. Particular care

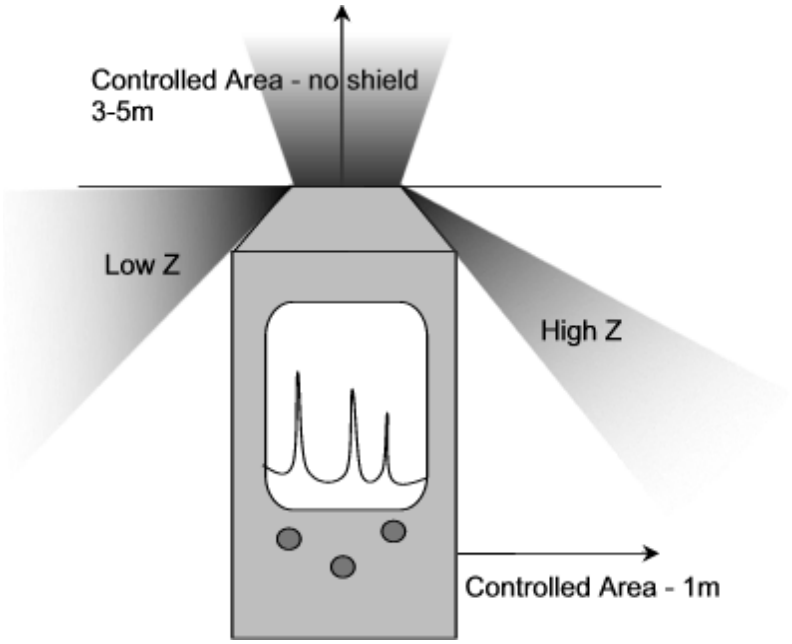
should be taken when obtaining second-hand equipment, to ensure that appropriate information is passed on and that all the safety features are fitted and working.

As well as specifying dose limits and the need to keep radiation exposures as low as reasonably practicable, IRR99 also include the following requirements for this equipment:

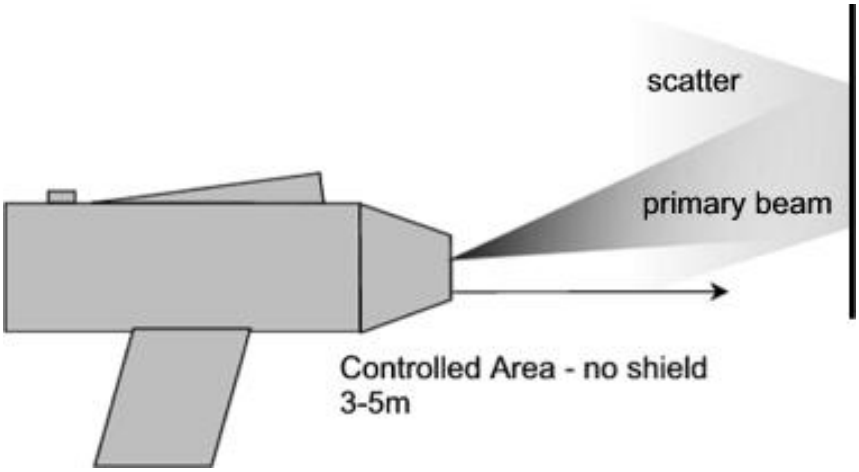
- Notifying the Health & Safety Executive (HSE) at least 28 days prior to first use. See http://www.hse.gov.uk/radiation/ionising/notification.htm
- Consulting a suitable Radiation Protection Adviser (RPA) to advise on compliance with the regulations. The Society for Radiological Protection maintains a database of RPAs. (see http://www.srp-uk.org/rpa-2000)
- Carrying out a prior risk assessment, that considers normal operations, possible radiation accidents and identifies the steps needed to restrict radiation exposures. These should include engineering controls (including safety and warning systems) and safe working procedures (see appendix 2). More information on the required content of the risk assessment is given in paragraphs 44 and 45 of the Approved Code of Practice. It is recommended that the RPA is consulted when preparing the risk assessment.
- The risk assessment and RPA should determine whether any Controlled Area needs to be designated. This type of equipment is likely to require the designation of a Controlled Area – which may extend up to a few metres in the main beam if not adequately shielded. The operator **must** prevent access by all persons to this Controlled Area.
- Operators must receive training in the safe use of the equipment and the radiation risks and safety requirements. This training should include a practical demonstration of the radiation levels around the equipment when in use.
- A programme for checking and maintaining safety systems and monitoring radiation levels (including the enclosure, if used).
- Use of finger dosimeters (TLDs) is recommended. These can help demonstrate that radiation exposures are being properly restricted and are especially useful for new users.
- Local Rules should be written, containing the safe working instructions and the contingency plans for dealing with radiation accidents. A suitable Radiation Protection Supervisor (RPS) should be appointed to oversee compliance with these Rules.

Photograph courtesy of Brüker

Appendix 1: Radiation beam profile



a) View from above



b) View from the side

The radiation profile will vary depending on whether there is an absorbing material (high Z, such as metals) or a scattering material (low Z, such as plastics) in front of the beam. The dose rates in the region surrounding the user end of the instrument will be higher for scattering material. For extended use on this type of material, the instrument should be used in a test stand.

Appendix 2: Safety requirements for handheld XRF Analysers

A Engineering controls and design features

Analysers have a number of design features to prevent misuse of the equipment and reduce operator exposure. Actual features may vary between equipment manufacturers but those listed below represent the best standards of engineering controls, that can be used as a checklist by which to compare available devices.

- A clear warning on the equipment to indicate that it is capable of emitting X-radiation.
- Key-operated or password-protected to prevent unauthorised operation.
- A housing designed to shield against leakage of X-rays.
- An exposure control which must be pressed continuously to generate X-rays. Handheld units should be designed for **two-handed** operation (to keep both hands away from the beam).
- A fail-to-safety warning light to indicate when X-rays are being generated.
- A proximity sensor which prevents X-rays being generated without a sample held against the aperture. Where this is not practical, a low-count (backscatter) interlock should be fitted. Ideally, both safety systems should be fitted.

Some devices provide all of the above engineering controls but it should always be confirmed that they are properly activated and working. It is also a requirement that this type of equipment is used within a local enclosure, wherever this is reasonably practicable, for example where measurements are done on small samples that can be taken to the analyser. Enclosures should provide:

- Adequate shielding, i.e. such that the dose rate outside the enclosure is below 2.5 µSv/h
- A safety system will prevent X-rays being emitted while the hands are inserted into the enclosure.

B Safe Working Procedures

The requirements of IRR99 are listed in the main guidance. In terms of the safe working procedures that should be included in Local Rules, the key elements are:

- The equipment should only be repaired/maintained by properly trained and authorised persons. Equipment should be immediately taken out of use if it is suspected of being damaged or any of the safety and warning systems are not working.
- The main beam must never be pointed at any parts of the body. Samples should not be held in the hand during measurements.
- The main beam should be fully intercepted by the sample. If a sample under test is too small to completely cover the aperture then this should be taken to a test stand within a local enclosure.

Enclosures should be designed to provide adequate shielding and should be interlocked to prevent accidental exposures.

- All persons should be excluded from the Controlled Area during measurements.
- The battery pack should be separated from the instrument when not in use and only attached when all preparations have been satisfactorily completed and the operator is ready to start measurements.
- The equipment should be securely stored when not in use to prevent unauthorised use.
- Only trained personnel should be approved for using this equipment. They should ensure that they have been appropriately trained and have read and understood the instructions for use.
- Use of a suitable radiation monitor at all time to carry out other radiation protection measures (e.g. check dose rates around enclosure) as recommended by the RPA.
- Specification of a radiation protection programme to monitor exposures by the use of personal dosimetry devices and/or other suitable means and to set an investigation level to ensure exposures are ALARP. A programme utilising finger TLDs for an initial period is recommended.
- Measurements on small work pieces/samples should be made within a shielded and interlocked enclosure
- Exposure times should be as short as possible.
- Operators should be the only ones allowed access to keys and passwords to minimise potential misuse.
- As a general rule, personnel should not be allowed within 3 metres in front of the primary beam and 1 metre to each front side, unless there is a solid barrier blocking the entire useful beam, such as floor or wall.
- Visual inspection of equipment before use should always be carried out by the operator to inspect for any damage.
- Secure storage when not in use which should ensure control of the device in terms of its location on every working day and who has responsibility for the device when removed from storage. The equipment should be made secure, when not in use, to ensure that unauthorised users do not have access to the equipment.

The radiation employer should periodically check to ensure that the above matters are adhered to and prompt action taken where these measures break down.

C Contingency Plans

Contingency plans to deal with an unintended exposure must be produced in order to restrict any exposure that arises from an accident or incident. The RPA should be consulted and typically contingencies should address events such as:

- Dropped analyser
- Physical damage to the analyser
- Theft and loss of analyser
- Exposure not terminating
- Malfunctioning equipment
- Overexposure or unintended exposure
- Unauthorised use of analyser
- Fire or explosion

Contingency plans must be included or at least be referenced in Local Rules and all relevant employees must receive training in the required actions.

References

1. Work with Ionising Radiation, Approved Code of Practice (ACOP) and guidance in support of IRR99. ISBN 0 7176 1746 7 reference L121 HSE Books

2. IEC 62495 Nuclear instrumentation - Portable X-ray fluorescence analysis equipment utilizing a miniature X-ray tube

The Society for Radiological Protection, a Chartered body, is the UK Associate Society affiliated to the International Radiation Protection Association (IRPA). It is a major scientific society for all who are concerned professionally with the safety aspects of ionising and non-ionising radiation in education, central and local government, industry, medicine and research.

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