Prior Risk Assessment

For Users of Fischer XRF Instruments

For Those Models Where Dose Rates 0.1m From Enclosure Do Not Exceed 1 µSv/h

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1 Introduction

1.1 Regulatory requirement for a Prior Risk Assessment

This Prior Risk Assessment (PRA) has been prepared for users of Fischer XRF analysers, in accordance with Regulation 7 of The Ionising Radiations Regulations 1999 (IRR 99) [1] and takes account of the associated Approved Code of Practice (ACOP) [2] Paragraphs 44 and 45.

The Assessment specifically addresses the radiological risks associated with those Fischer XRF instruments where the dose rate at 0.1m from the surface of the instrument does not exceed 1 µSv/h. It takes no account of any radioactivity in test items or any other unrelated radiological hazards which may be present in the workplace.

1.2 Overview of the equipment

Fischer provide a range of X-ray fluorescence instrumentation (Figure 1) designed for coating thickness measurement and materials analysis. The instruments which are the subject of this assessment are based on 50 W X-ray tubes, and operate at an accelerating potential of 50 KV and tube current of 1 mA.

Figure 1. The range of Fischer XRF instruments

The principal of operation is shown succinctly in the diagram from the Fischer X-ray Product overview, which is repeated here in Figure 2.

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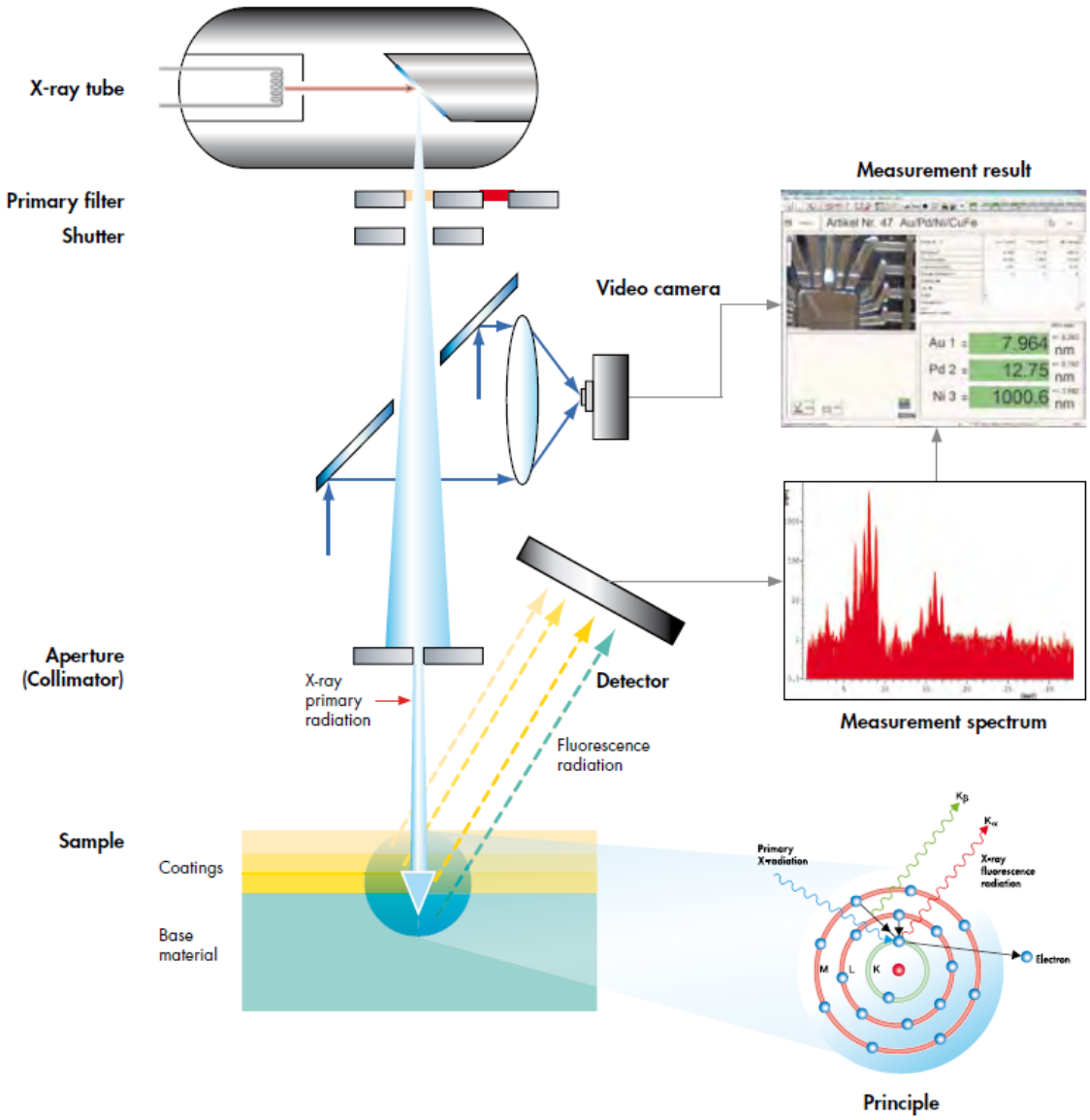

Figure 2. Principle of operation of the Fischer XRF instruments

The instruments operate with continuous power to the X-ray tube in normal operation, but with the useful X-ray beam effectively switched “on” and “off” by a shutter which is highly effective at attenuating X-rays at this energy. The X-ray tube, analysing sensor and test items are housed within an enclosure with interlocks preventing access to the interior of the enclosure when the X-ray beam is irradiating the enclosure interior.

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2 Unmitigated Radiation Hazards

2.1 External Radiation

The dose rate close to the focal spot of the X-ray tube is very high (of the order of Gy per hour at 1 m from the focal spot) and would be capable of giving rise to deterministic radiation effects (burns to hands) with momentary exposure of the hands in close proximity to an unshielded generating X-ray tube.

However, this is of little consequence to the user, as engineering controls (Section 3.1) virtually eliminate any likelihood of access to the X-ray tube during generation in all reasonably foreseeable circumstances.

2.2 Internal Radiation

There are no internal radiation hazards associated with radiation generated by electrical equipment operating at these low accelerating potentials.

3 Dose Restriction Measures

3.1 Engineering Controls, Design Features, Safety and Warning Devices

The use of the Fischer XRF instruments is subject to a key switch, which is in accordance with ACOP Paragraph 97. With this key switch off, the power is removed from the X-ray tube and the hazard removed. Turning the key clockwise into the “ON” position starts a system checking procedure, and only when the absence of faults on any safety circuit is confirmed does the high voltage start to be applied to the X-ray tube.

During use (i.e. with the X-ray set energised and the shutter open), the shielding around the tube and incorporated in the instrument enclosure itself, is such that the dose rate at 0.1 m from the surface of the instrument enclosure is nowhere greater than 1 µSv/h.

The generation of the measurement / analysis beam is normally terminated by the automatic closure of the shutter which attenuates the beam such that dose rates within the enclosure are much less than 1 µSv/h (stated by the manufacturer as giving no excess count rate on a Mini Instruments 900 with a Type 42A probe, when positioned within the enclosure).

Should the shutter fail to close, the control system recognises that “opto sensor” has not triggered and shuts off the power to the X-ray tube. Requiring a positive trigger from this sensor to confirm shutter closure can be regarded as “fail safe”.

Exposure of the operators hands is prevented by the interlock system on the access hood. The opening of the access hood triggers dual micro-switches which will promptly close the shutter. In order for the shutter to open, positive signals from both micro-switches must be detected.

It is specifically noted that the action of closing the access door (i.e. correcting the fault which prevents the X-ray on / shutter open condition, does not automatically re-start the exposure. The operator must restart the exposure

These exposure controls are in accordance with those stated in ACOP Paragraph 87.

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The warning signals are clearly visible and are based on highly reliable LED warning lights which indicate the following:

- POWER ON which indicates power to the instrument
- HV ON which indicates that power is supplied to the X-ray tube control boards
- X-RAY ON which indicates that sufficient current and voltage is supplied to the X-ray tube, such that it is generating X-rays, and
- SHUTTER OPEN which indicates that X-ray irradiation of the interior of the instrument is taking place.

If any conflict in the interlock system indicators is detected (for example, if only one of the two door micro-switch is activated with the door closed), a CONTROL LED flashes to indicate a fault.

These warning devices are in accordance with ACOP paragraphs 99 and 100.

3.2 Systems of Work

Due to the engineered safety features incorporated into these gauges, the requirements for systems of work are minimal and are limited to the following:

- All users of the instrument must receive information, instruction and training in relation to the instrument and its safety systems and the following:
  - Information on the risks to health created by exposure to ionising radiation, including information for female employees on the risk to the foetus.
  - The precautions to be taken
  - The importance of complying with the various aspects of the regulations, in particular, their legal duties as an individual, of which those relevant to this work are:
    - Not to intentionally or recklessly misuse or without reasonable excuse interfere with any source of ionising radiation.
    - Not to knowingly expose yourself or any person to ionising radiation to an extent greater than reasonably necessary for the purposes of the work
    - Exercise reasonable care while carrying out work with ionising radiation
    - To notify your employer if there is reasonable cause to believe that you or some other person has received a significant unintended exposure.
    - For female employees to notify their employer in writing as soon as they discover they are pregnant.
- Maintenance of the instrument and its safety features / warning devices must be conducted in accordance with the manufacturers' or suppliers' instructions, and will only be undertaken by their agents.
- Where the equipment is damaged or it is suspected that any safety feature or warning device has failed to operate correctly, the user is to
  - disconnect the instrument from the power supply,
  - inform their employer and
  - ensure that a legible notice is attached to the instrument in a prominent position warning others of the fault and prohibiting further use.
- Any keys or passwords required to prevent unauthorised use of the instrument must be kept securely.

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In the absence of any need for designated areas in normal use (Section 7), these systems of work must be included in a work instruction or other document intended for users of the instrument.

3.3 Personal Protective Equipment

PPE is not appropriate for the radiation protection of users of these Fischer instruments as the use of engineering controls and systems of work restrict the exposure to a level that can be regarded as ALARP.

4 Identification Of Those At Risk

This instrumentation is intended for use in the work place. With the shielding afforded by the shutter and the enclosure reducing dose rates at 0.1 m from the instrument to no greater than 1 µSv/h, only those employees who are working with the instrument are likely to receive any dose.

The magnitude of the dose rate outside the instrument enclosure is such that other employees in the workplace and members of the public would not be at risk. As such, the applicable dose limits are those which apply to employees aged 18 and over, and are as follows:

- 20 mSv effective dose in a calendar year
- 500 mSv equivalent dose to any 1 cm^2 of skin in a calendar year
- 500 mSv equivalent dose to the hands, forearms, feet and ankles in a calendar year
- 13 mSv equivalent dose to the abdomen of a woman of reproductive capacity in any consecutive 3 month period

5 Dose in normal routine operations

Acknowledging that the extent of the maximum 1 µSv/h dose rate at 0.1 m from the surface of the instrument is insufficient to irradiate the whole body, the annual effective dose of any employee working with this instrument is unlikely to exceed 1 mSv.

Equivalent dose to skin or extremities, can be calculated on the assumption that either the skin or an extremity remains close to the instrument for a period of 2000 hours in the calendar year, and consequently receives an equivalent dose of 2 mSv. Such a dose, calculated on very conservative assumptions, is far less than one-tenth of the 500 mSv calendar year equivalent dose limit.

In terms of variability of radiological conditions, the test conditions that have generated the radiological data used in this assessment have been “worst case”. Although workload can be expected to vary, again the assessment has been made on worst case assumptions.

6 Accidents, Incidents and other Unwanted Occurrences

Provided there is no modification or deliberate by-pass of an interlock system, the fail-safe interlock systems on both the shutter mechanism and the access door render it unlikely that any reasonably foreseeable accident, incident or unwanted occurrence would give rise to a radiation accident.

7 Conclusions and Recommendations

Despite the highly significant dose rates present close to the X-ray tube when it is generating radiation, the engineering and design features are suitable and sufficient to prevent operators being exposed to this intense radiation source.

With the engineering controls, safety features, warning signals etc. in operation, it is most unlikely that operators of this equipment would receive an annual effective dose of more than 1 mSv, or an equivalent dose of more than one tenth of an equivalent dose limit.

With adherence to the systems of work identified in this assessment the operators can be assured that their radiation dose is at a level which is normally regarded as occupationally insignificant and which may be considered As Low As Reasonably Practicable (ALARP).

The specific conclusions of this assessment, in relation to the requirements of ACOP Paragraph 45 are as follows:

- In order to ensure radiation exposure remains ALARP, the radiation employer must adopt the systems of work identified in this assessment and ensure that the instrument is maintained in accordance with the manufacturers' or suppliers recommendations.
- The use of PPE in relation to the operation is not appropriate, as the engineering controls and systems of work already restrict exposure to ALARP.
- The radiological conditions associated with the use of this instrument are sufficiently low as to make it unnecessary to change working conditions etc. for a female employee who declares her pregnancy.
- A Dose Investigation Level of 1 mSv effective dose shall be adopted.
- As no reasonably foreseeable accident, incident or unwanted occurrence could give rise to a radiation accident, there is no need for written Contingency Plans that would otherwise be required by Regulation 12.
- All those working with the instrument shall be given suitable and sufficient information, instruction and training as detailed in Section 3.2.
- Although "Controlled Area conditions" exist within the enclosure when the X-ray beam is exposed, as access to these dose rates is effectively prevented by the engineering controls, a Controlled Area need not be designated. As dose rates outside the instrument enclosure are sufficiently low as to make it unlikely that any operator will receive an effective dose of more than 1 mSv or an equivalent dose greater than one-tenth of any equivalent dose limit, and sufficient invariant such that there is no need to keep radiological conditions under review to determine whether a Controlled Area needs to be designated, there is no need to designate a Supervised Area.
- In the absence of designated areas, there is no need to write Local Rules or appoint one or more Radiation Protection Supervisors. It is, however, recommended that the systems of work identified in this assessment are incorporated into working instructions.
- As the dose to an employee is unlikely to exceed an effective dose of 6 mSv or an equivalent dose of more than three-tenths of any equivalent dose limit, and as it is not reasonably foreseeable that this instrument could give an over exposure in several minutes (ACOP 368), there is no need to classify any employee who works with this instrument.
- Although, in the absence of designated areas, many of the requirements of IRR 99 do not apply to the use of a Fischer XRF instrument, it is recommended that a manager with health and safety responsibilities is appointed to ensure that it is maintained in accordance with the manufacturers' recommendations and to ensure that the radiation employer meets the remaining requirements of IRR 99. In this, the radiation employer is required to consult and appoint a suitable Radiation Protection Adviser (RPA).

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8 References

1 The Ionising Radiations Regulations 1999, Statutory Instruments 1999 No 3232.
2 Work with ionising radiation: The Ionising Radiations Regulations Approved Code of Practice and Guidance, L121