GUIDANCE FOR INDUSTRIAL MOBILE RADIOGRAPHY[1]

Draft for discussion

INTRODUCTION

Industrial mobile radiography involving radioactive (gamma) sources and x-ray equipment should be subject to national regulations in each Member State, in accordance with Council Directive 96/29/EURATOM (Basic Safety Standards). Radiography operators are expected to comply with such regulations, which in turn are expected to involve the observance of safe working procedures. This document provides additional guidance in the form of specific procedures for industrial mobile radiography to help ensure that a satisfactory standard of radiation protection is achieved in practice. It is aimed specifically at industrial radiography operators and radiography staff, but is also relevant to radiography clients and regulatory authorities.

This guidance relates specifically to industrial radiography using mobile x-ray and gamma sources under "site" conditions. It does not consider radiography within a specially designed enclosure ("compound radiography"). It is stressed, however, that it is almost always safer to undertake radiography in an enclosure, and that mobile radiography should only be undertaken where it can be shown that an enclosure is not reasonably practicable.

In preparing this guidance, account was taken of the IAEA Draft Safety Guide "Radiation Safety in Industrial Radiography", DS408.

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[1] The term "industrial mobile radiography" is used to describe industrial radiography *not* undertaken in a purpose-built enclosure; the item under inspection is radiographed in-situ using portable equipment. It may also be referred to as "site", "open-shop" or "portable" radiography.

PART 1 – Organisation and Personnel

1.1 Authorisations and notifications

Individual Member States will have their own system of authorisations for radiography sources (gamma and x-ray), and radiography operators will need to seek authorisation in accordance with the relevant national regulations in **each** Member State in which they operate.

Gamma radiography sources will normally be classified as High Activity Sealed Sources (HASS) in accordance with Council Directive 2003/122/EURATOM. The relevant provisions for HASS specified in national regulations should be implemented by the radiography operator.

It is also suggested that regulatory bodies should require that they notified when radiography is planned to take place at a particular site. The arrangements will depend on the relevant national regulations, but the aim should be to obtain sufficient details to enable regulatory inspections of mobile radiography in progress.

1.2 Personnel

Any person concerned with radiography and other work involving the use of ionising radiation will fall into one or more of the following categories:

1.2.1 Radiation Protection Expert (RPE)[2]

Every radiography employer should appoint a person or organisation who should be capable of giving expert advice on all aspects of radiation protection related to mobile radiography.

The RPE is an important source of advice on the protection of persons from ionising radiation and should be able to give advice to the employer concerning:

- Optimisation of exposures and the setting of dose constraints
- Selection and training of RPOs and other staff
- Designation of controlled areas for mobile radiography
- Dosimetry and monitoring arrangements
- Investigation of exposures above dose constraints/limits
- Hazard assessment and emergency preparedness arrangements.

[2] The term Radiation Protection Expert (RPE) refers to the post defined in national regulations that is equivalent to the definition of the "Qualified Expert" in Council Directive 96/29/Euratom, or in the International Basic Safety Standards (Safety Series No. 115, IAEA, Vienna, 1996). That is: *"An individual who, by virtue of certification by appropriate boards or societies, professional licenses or academic qualifications and experience, is duly recognized as having expertise in a relevant field of specialization…"*

1.2.2 Radiation Protection Officer (RPO)[3]

The employer should appoint in writing one or more employees to supervise the work with radiography sources. RPOs should have received appropriate training in radiation protection, including the nature of the radiation hazard during mobile radiography, the relevant regulatory requirements, and the safe working procedures required. They should also be capable of putting the emergency procedures into effect.

An RPO should be present on site whenever work with radiation sources is undertaken. The names and contact details of the RPO(s) should be displayed on the site where radiography is undertaken. There should be a sufficient number of RPOs to ensure adequate supervision of the work.

1.2.3 Radiography Personnel

The potential for exposure during mobile industrial radiography is significant. As such, **every** radiographer, radiographic assistant and RPO should be subject to individual dose assessment (see 1.4) in accordance with the requirements of national regulations.

Radiography personnel should be made fully aware of the hazards of ionising radiations and have received training in radiation protection. This should cover the requirements of relevant regulations, safe working procedures and the emergency plans.

Radiographers and radiographic assistants should be given specific instruction in the method of operation of every item of equipment which they will use; this is especially important for source exposure equipment and dose-rate meters. They should also be taught to recognise fault conditions and other emergencies, and to follow the emergency procedures. At least once a year they should practice, under the direction of the RPO, execution of emergency plans (see section 4) including source recovery procedures using a dummy source.

1.2.4 Outside Workers

On some sites, for example nuclear installations, the radiography may need to be undertaken within an existing radiation controlled area. In such cases, the radiography staff will be regarded as Outside Workers, as defined in Council Directive 90/641 EURATOM. In such cases, the Outside Worker requirements in the relevant national regulations will need to be observed, including the requirements for training of personnel and the issue of radiation passbooks.

[3] The term "Radiation Protection Officer (RPO)" refers to an individual appointed by the registrant/licensee/employer to supervise or oversee the execution of practices. Defined in the IAEA international Basic Safety Standards as: "*An individual technically competent in radiation protection matters relevant for a given type of practice who is designated by the registrant or licensee to oversee the application of the requirements of the standards*".

1.2.5 Other Persons

Any persons, such as members of the public or employees, who are not directly involved with the work, should be excluded from radiography controlled areas, and from operating radiography exposure equipment. Such persons should be made aware of the existence of a radiation hazards and the importance of complying with safety barriers, signs and warnings.

1.3 Health Surveillance

Requirements for the health surveillance of radiation workers will be specified in national regulations. It is recommended that radiography personnel should be subject to periodic medical surveillance, arranged by the employer. There have been examples of radiographers receiving localised radiation injuries, for example to the hands, and the arrangements for medical surveillance should include a requirement to check for signs of any such injuries.

1.4 Individual monitoring of workers

1.4.1 Personal dosemeters

The employer should make arrangements with a dosimetry service for the assessment of individual doses to all radiography personnel, and for the keeping of dose records. This will normally be done through the issue of passive dosemeters (for example, thermoluminescent or film-based dosemeters), although electronic dosemeters may be used if they are of a type approved by the national authorities for such purposes.

The normal wearing period for dosemeters for mobile radiography is 1 month, although shorter wear periods may be appropriate where the potential for exposure is especially high. Even where doses have been shown to be low in the past, longer wearing periods are not advised due to the difficulty in retrospectively investigating any unusual results.

No dosemeter issued to a particular individual should be worn by other persons. Lost dosemeters should be reported immediately, and a replacement dosemeter issued before continuing work.

1.4.2 Dose records

The employer should arrange to receive records of the assessed dose for each dosemeter issued. The employer should have a system for reviewing these records upon receipt to check whether any unusual doses have been recorded - unusually high doses can indicate poor working practices or that an accident has occurred; unusually low doses can indicate that dosemeters are not being worn properly.

1.4.3 Dose constraints and dose investigations

Employers are encouraged to set dose constraints for their employees – these should represent the doses expected from well-managed mobile radiography operations. For comparison purposes, information on average doses from industrial radiography operations is published by national authorities, and is also available from ESOREX (www.esorex.eu).

If a dose constraint is likely to be exceeded, employers should investigate whether sufficient measures to restrict radiation exposures are being taken. If a person receives a radiation dose in excess of the Member State's legal dose limits, the actions specific in the relevant national regulations must be implemented.

1.5 Co-operation with the client and other employers

Both the radiography operator and the radiography client (i.e. the operator responsible for the site) have a role in ensuring a good standard of radiation protection. Local factors such as poor access arrangements and poor lighting can adversely affect the doses received by persons during mobile radiography. It is important that sufficient time is devoted by both parties to planning the work, and that information is exchanged, for example as listed below:

Information that should be supplied to the client

- Details of the radiation sources to be used
- Details of any on-site storage arrangements for gamma sources
- Names of RPO(s) and RPE(s), and how they can be contacted
- Places and times where work will be carried out, a brief description of work, and any special arrangements to restrict exposure, such as local shielding, barriers and warning devices
- The location and size of the planned controlled area, and what the dose rate at the perimeter of this area is expected to be
- Copies of safe operating procedures and emergency plans.

Information that should be sought from the client

- Permission to bring radiation sources on site, and to exclude other persons from the designated radiography area
- Information on any special site conditions or hazards which may affect the work
- Client's rules for contractors, the site emergency procedures and location of first aid facilities
- Names and locations of key personnel, e.g. site safety officers.

1.6 Control of Gamma Radiography Sources

1.6.1 Source accountancy and records

Gamma radiography sources should be kept in secure storage (See Part 4) when not in use. At all other times, they must be under the direct supervision of trained radiography staff.

Accurate records must be maintained for all gamma radiography sources. The data recorded should include:

- The date of receipt
- The serial number of the sealed source
- The nuclide and activity at a specified date
- The storage location of the source
- The date and time that a source is taken from or returned to the storage location, and the place to which the source has been taken
- The date and manner of disposal.

An inventory check of sources should be carried out on each working day by an authorised person. The records should be retained for an appropriate period, as required by national regulations.

1.6.2 Loss of gamma radiography sources

The employer should be notified ***immediately*** if it is suspected that a source has been lost or stolen. The employer should organise a thorough search. If it is not located quickly, the relevant national authorities should be notified.

1.6.3 Transport of gamma radiography sources

Radioactive sources must be transported in accordance with the requirements of ADR, and radiography operators should seek advice from a suitably qualified Dangerous Goods Safety Adviser (DGSA).

1.7 Equipment Tests and Checks

Many mobile radiography accidents have occurred due to faulty or poorly maintained equipment. Consequently it is extremely important that radiography operators put in place a system for inspecting and maintaining radiography equipment, supported by appropriate record-keeping.

1.8 Safe Working Procedures and Emergency Plans

The procedures for safely undertaking mobile radiography, in accordance with the national regulations, should be written down by the radiography operator. These should include:

- Name(s) and responsibilities of key personnel (e.g. RPOs, RPEs, etc.)
- The operating instructions for radiographic equipment, including any safety and warning systems
- The procedures for setting up barriers and restricting access for controlled areas
- Monitoring and dosimetry arrangements
- Emergency plans.

The emergency plans should specify the actions to be taken in the event of an accident that could give rise to radiation risks to people. Accidents that should typically be considered include:

- Accidental entry into a radiographic controlled area
- Failure to properly terminate an exposure (x-ray or gamma)
- Damage to a gamma radiography source
- Loss of a gamma radiography source
- Transport accidents involving gamma radiography sources.

The radiography operator should ensure that all relevant persons have read and understood the written procedures.

1.9 Site Safety Audits

It is recommended that safety checks be made on a random basis to ensure that operations on site are being carried out according to the required safety standards. Such checks should be carried out by a safety officer or site/area manager.

Radiography clients may also wish to undertake their own audits, i.e. to check that the safety of their site and staff is being maintained by the radiographers. In such cases, audits should not normally involve access into a radiography controlled area.

PART 2 – Radiographic Equipment

The proper design, selection, and use of radiography equipment are fundamental to radiation safety. All equipment should be maintained in good, clean, working order, be periodically inspected and records of inspection, maintenance and repair kept. This is described further in 3.5.

All X-ray machines and gamma exposure containers should be provided with a key which is designed to prevent unauthorised use. Keys should be held in the custody of authorised persons or otherwise securely stored.

2.1 Gamma-ray Equipment

2.1.1 Radiography Sources

A sealed source for radiography consists of a small, sealed, metal capsule inside which the radioactive substance is completely contained. Gamma radiography sources should meet the requirements for "special form" radioactive material. Radiographers should be shown dummy sources of the normal types used so that they can recognise real ones in an emergency.

Sources should be selected to give reasonable exposure times compatible with optimised doses. In selecting a source it is important that a clear picture of the conditions to be met on site is obtained. High activity sources can achieve a large number of exposures in a given time but they produce high dose rates, a large controlled area has to be set up, and they can present acute problems in an emergency.

2.1.2 Exposure Containers

Exposure containers should comply with the requirements of ISO 3999-1 (2000)[4]. Containers which do not comply with this standard may be used provided it can be demonstrated that the protection to people is equivalent or better. Exposure containers also have to be transported and it should be ensured that they meet the relevant ADR requirements.

[4] ISO 3999 gives information on exposure rate limits, safety devices, handling facilities, tests for vibration, shock and endurance, test procedures, requirements for marking the container and for identification of the sealed source in the container.

Gamma radiography exposure equipment should be examined at least annually by the manufacturer or a qualified service agent, and where necessary overhauled and certified as being in good operating condition.

2.1.3 Types of Exposure Containers

Three types of gamma radiography container have been used for mobile radiography:

(a) A **shutter-type** container consists of a block of shielding material at the centre of which the source is located. A portion of the shielding can be removed or rotated to expose the source, thus acting as a shutter. Due to the weight of shielding, this type is only practicable for use on site with relatively low energy or low activity sources.

The solid angle of the useful beam is not usually more than 60 degrees. Therefore this type of container offers a convenient method of limiting the useful beam. However, additional collimation may still be required to limit the useful beam to the minimum size necessary for radiography.

(b) A **projection-type** container consists of a block of shielding material with an internal tube so that the source when not in use is shielded within the container. The most common type of radiography container has an S-shaped tube, although there are others where a type of shutter is provided to enable the source to be exposed.

The source is exposed when projected out of the container - guide tubes **must** be used, and should be as short as reasonably practicable. The end of the guide tube should be placed in a collimator designed to limit the beam to the minimum size necessary for the work. The control cable length and layout should be selected to minimise the dose to the operators.

With **all** types of projection container a dose-rate meter **must** be used to ensure that the source has been shielded safety after every exposure.

(c) Use of **manual extraction** (“torch” type) source exposure containers is **not** recommended. Experience has shown that the doses received by operators can be significantly higher than those received by the operators of types (a) and (b) above.

2.1.4 Exposure container locks

The exposure container should be provided with an integral lock. The lock should be either of the safety type, i.e. lockable without a key, or an integral lock from which the key cannot be withdrawn while the container is in the working position. The lock should retain the source in the secured position and should not, if the lock is damaged, prevent the source being returned to the secured position.

Containers should be stored in a locked condition, with the keys removed. The keys should be kept securely in a place separate from the store, and only made available to persons authorised in writing.

2.1.5 Shielding

The standard of shielding to be provided in source exposure containers is given in ISO 3999-1 (2000). The dose rates near the container can be relatively high, even with the source in the secure position, and care should always be taken whenever exposure containers are handled.

Except where the source is being transported, a controlled area will normally need to be demarcated around the container, and stores will often need to provide additional shielding.

Many exposure containers use depleted uranium shielding, and such containers, even when empty, should be subject to the relevant controls for radioactive materials.

2.1.6 Transfer of sources between containers

If a source needs to be moved into a different container, this should be carried out by properly trained and authorised personnel, either by sending the source container to the source supplier, or by using specially-designed transfer equipment within a controlled area.

2.1.7 Emergency equipment

Additional equipment should be available for use to deal with emergencies such as detached sources, jammed sources and damaged containers.

2.1.8 Site storage arrangements for gamma radiography sources

The store should be robust, secure and bear an appropriate warning sign. The store security arrangements should be capable of detecting unauthorised entry, i.e. such that the theft of a source can be prevented from happening.

The store should also provide any additional shielding required, i.e. so that a controlled area need not be designated outside the store.

The store should not be used for keeping items other than the exposure containers and ancillary equipment. In particular, other hazardous materials (e.g. highly flammable materials, pressurized gas containers, explosives, corrosive chemicals, etc.) should be stored well away from the radioactive materials store.

The source accountancy requirements described in Part 1 should be observed at all times.

Vehicles should not be used as a temporary storage solution – if storage on site is required, a proper store, as described above should be provided.

2.2 X-ray Equipment

2.2.1 Cable Lengths

Much can be done to minimise the radiation doses received by radiographers by placing the control panel as far as possible from the X-ray tube head. Lengths of cable should normally be not less than 20 metres for X-ray generators up to 300 kV, and longer for more powerful equipment. Cables should be laid out as straight as possible to maximise the benefit from distance.

2.2.2 Collimation and Filtration

Collimators should be provided to reduce the useful beam to the minimum size necessary for the work. This, in conjunction with local shielding, restricts the size of the controlled area and is an important means of reducing the radiation dose.

Dose rates in the vicinity of the X-ray set can be reduced by the addition of suitable filtration. This absorbs low energy radiation which otherwise increases scatter but does not significantly penetrate for example steel to affect the radiograph (in many cases added filtration can provide a better image quality).

2.2.3 Warning Signals

Adequate warning should be given to all persons in the vicinity immediately prior to and during a radiography exposure (see Part 3 for more details). For X-ray equipment the warning signals should operate automatically.

It is important to ensure that the cable length is sufficient to allow the warning signals to be placed close to the X-ray tube head and repeated if necessary close to the radiographic film. The warnings should be duplicated on the control panel.

The warning signals should be interlocked with the X-ray machine so that the X-ray tube cannot be energised unless the signals are properly connected. Interlock override devices should not be fitted.

2.2.4 Electrical Safety

Some electrical faults in X-ray equipment have lead to serious radiation incidents. It is essential that all X-ray equipment conforms to national and EC electrical requirements.

Equipment must be correctly connected to earth. All metallic enclosures, including inter-connecting flexible braided cables, the power supply unit (transformer/generator), X-ray control equipment, tubehead, warning signal device **and** the workpiece, should be electrically bonded together.

All electrical equipment should be periodically examined, tested and certified as safe by a suitably qualified electrician.

2.3 Radiation monitors

2.3.1 Dose-rate meters

The most important single item of safety equipment is a radiation dose-rate ("survey") meter, which should be:

- light, robust, portable and capable of being used in bad weather and poor light, as required;

- capable of measuring the specific type of radiation involved (e.g. x-rays within a certain kV range, gamma rays from iridium-192, cobalt-60, ytterbium-169, etc.) able to measure dose rates from a few microSieverts per hour (for barrier-setting purposes) up to 2 milliSieverts per hour (for checking containers, etc); and
- tested by a qualified person before being taken into use, re-tested annually, and after every repair which could affect its accuracy. Records of the test and the results should be kept.

2.3.2 Personal Alarm Monitors

These pocket-sized devices emit an audible alarm, normally above a pre-set dose or dose rate level. All persons directly involved with radiography should be provided with one. However, they should only be used in addition to dose-rate meters and not as a substitute for them.

Some models of alarm also provide a measurement of the accumulated dose. This can be very useful for indicating the pattern of exposures, and so help optimise protection measures. This feature is also extremely useful when responding to accidents (where high doses can be received quickly), and the use of this type of alarm is strongly recommended in such circumstances.

Audible alarm monitors must be tested periodically in accordance with the national requirements.

PART 3 – Safe Working Procedures

3.1 Reducing Exposures – key issues

For mobile radiography, the following key issues should always be remembered.

- The choice of radiographic method, radiography source, ancillary equipment and type of radiographic film all affect the doses received by operators.
- The beam should be limited by using suitable collimation to the minimum size reasonably necessary for the work.
- Persons outside the useful beam can still receive significant doses due to scattered radiation from surrounding air and the article being radiographed. A combination of local shielding and distance from the source should be used to restrict doses.
- Every source in use should be under the supervision of a trained radiographer at all times.

3.2 Planning

Mobile radiography has to be carried out in a wide variety of work places under differing working conditions and both day and night. Because of the nature of the radiation hazard and the problems created by the ever-changing work situations, careful planning of the method of work is essential if unnecessary risks are to be avoided.

When planning the work the main objective should be to keep radiation exposures as low as reasonably practicable. Key issues are listed above - in addition, when planning a particular job the following should also be considered:

- The arrangements for contacting and co-operating with the Client and other relevant employers.
- The location and size of the controlled area, points of potential access, and the methods to be used to exclude non-radiographic personnel throughout the work.
- The number of radiography staff required. At least **two** trained persons should be employed for each source in use. At least one should be an experienced radiographer; and the other a trained radiographic assistant. This is a minimum requirement – more personnel may be required, for example to ensure that access to the controlled area can be effectively managed. At least one RPO will also need to be on site, as described in Part 1.
- The working conditions within the controlled area. Issues such as restricted access (e.g. confined spaces) and adequate lighting should be considered, as should the need for radiography staff to communicate with each other during the work.
- The position of the control point, operator and other personnel.
- The type number and location of safety and warning devices to be employed during the work.
- Site storage arrangements for gamma radiography sources (see 2.1.8).

3.3 Dose Rate Monitoring

At least one suitable (see 3.5) dose rate meter should be available for use with each source. The battery condition should always be checked prior to operation, and the meter should be left switched on throughout the radiography work. In particular, it should be used to:

- Check that barriers are positioned correctly, i.e. that the maximum dose rate at the perimeter of the controlled area, as specified by the regulatory authorities, is not exceeded.
- Re-check the barrier positioning whenever the radiographic set-up changes.
- Monitor the dose rate at the control point and at any key positions inside the controlled area, for example if radiographers have to remain in the area during an exposure.
- **Always** check that the exposure has been properly terminated, and that gamma sources are correctly retracted.
- Check that source stores are adequately shielded.

3.4 Working on Site (demarcating the radiography area)

Before the commencement of any radiography work it **must** be ensured that:

- A suitable working dose rate meter is available, **and**
- All radiography staff are wearing personal dosemeters and personal alarm monitors.

3.4.1 Controlled area boundary

The controlled area needs to be sufficiently large to ensure that the dose rates outside the barrier are below the levels specified in the national regulations. However, very large controlled areas are difficult to effectively supervise, and should be avoided. If necessary, local shielding should be employed to reduce dose rates and help limit the size of the area.

Barriers should be erected before starting radiography. It is essential to calculate the approximate safe distances required for the particular circumstances. A dose rate meter should always be used during the first exposure (and each subsequent exposure whenever the radiographic set-up is changed) to confirm that the barriers are correctly positioned.

Existing structures may be used to help demarcate the area, provided that they do not give rise to an over-large controlled area. All access points to the area must be demarcated by a combination of rope barriers, warning signals and signs to provide a clear visual deterrent to persons.

The area must be searched prior to the first exposure to ensure that it is clear of unauthorised persons, and the barriers must be patrolled during exposures to check that such persons remain out of the area.

3.4.2 Warning Signals

Separate warnings **must** be given to persons in the vicinity (by visible or audible signals or both):

- Prior to an exposure (a pre-warning) and
- During an exposure.

The two signals should be clearly distinguishable. In the case of X-ray machines the warning signals should be integrated with the control circuitry so that they operate automatically. Similar warning signals are required for gamma radiography.

The signals should be positioned so that they are clearly visible/audible to all persons in the vicinity. Careful attention should be paid to the provision of warning signals near the source; and repeated if necessary at the position where the radiographic film is placed.

Suitable warning notices should be posted at positions of potential access. These signs should explain the pre-warning and exposure warning signals in use.

3.4.3 Control Point

Careful consideration should be given to the positioning of the control point:

- It **must not** be within the main beam during any exposure.
- It should be arranged to provide optimum protection for the operator compatible with supervision of access points to the area. If practicable, it should be outside the controlled area.
- Where it is not practicable to provide line of sight communication between the radiographers, a direct voice communication system is required.
- Wherever the control point is placed, arrangements should be made to ensure that it is not possible for unauthorised persons to initiate an exposure. This can be done by locking the gamma source container or removing the key from the X-ray set. The practice of disconnecting cables to prevent operation between exposures is not recommended.

3.5 Care of Exposure Equipment

Many radiation accidents have been caused by worn or damaged wind-out mechanisms and guide tubes on source containers. The majority of such accidents could have been prevented by proper maintenance and careful use of a dose-rate meter.

3.5.1 Gamma-ray equipment

A visual examination should be made before leaving the site to ensure that equipment is in a good general condition. The following should be attended to on a routine basis:

- The container should be cleaned after use and any mud or water wiped from the outside;
- Any screws or nuts on the outside of the container should be checked for tightness;
- Any moving parts, particularly those on projection-type equipment, should be lubricated in accordance with the manufacturer's instructions;
- Winding cables and extension tubes on projection-type equipment, should be coiled in such a way that they are not creased or bent;
- The threads on screw-type connections should be checked. If the threads appear to be crossed or otherwise unsatisfactory the container should be serviced; and
- Where the cable is detached, the exposed ends should be covered to prevent the ingress of dirt.

3.5.2 X-ray equipment

Maintenance of electrical equipment should be carried out in accordance with the manufacturer's instructions. All cables and connectors should be given a visual check before the equipment is put into use on site.

3.6 Before leaving site

It is very important that the radiographers confirm (using a dose rate meter) that all gamma sources have been successfully returned to the exposure container. It should also be ensured that all warning signs and other equipment used during radiography have been removed.

Finally, the radiographers should confirm to the client that the radiography work has been completed and that all radiation sources have been removed from site.

PART 4 – Emergency Preparedness

Before any emergency plans can be prepared a risk assessment should be undertaken to identify any reasonably foreseeable accidents, and evaluate the consequences of such accidents. Where possible, steps should be taken to prevent accidents occurring (e.g. through training and preventative maintenance). However, accidents are never totally avoidable, and this part covers the preparation and implementation of plans for dealing with likely to arise in the course of mobile radiography.

4.1 Development of Emergency Plans

4.1.1 Gamma radiography sources

Every employer should have written emergency procedures which should cover the action to be taken when an incident occurs with a gamma source. The procedures should be prepared in consultation with the RPO and RPE. On some sites, consultation may also be necessary with the radiography client.

The following topics should be covered in the emergency plans:

- The circumstances in which there will be an immediate cessation of radiography work
- Procedures for the emergency positioning of barriers and warning signs
- The names and contact telephone numbers of the people who need to be informed immediately, for example, the regulatory authorities
- Search procedures in the case of lost sources
- Procedures for recovering sources non-retracted sources – see 4.2
- Procedures to follow if a gamma radiography source is involved in a fire or a transport accident
- Procedures for dose assessment for those persons involved in the incident
- Responsibilities for the preparation of the incident report and its suggested content.

4.1.2 X-ray equipment

Emergency plans should be developed to cover any situation in which the equipment is accidentally energised or remains on unintentionally, and incidents involving unauthorised access into the controlled area during an exposure.

The plans should stress the need to isolate the machine; to leave it until it can be seen by the employer or the service engineer; and to record the details of any person who may have been involved in the incident. The equipment should not be moved until details such as position, beam direction, settings, etc have been recorded. This information may be required for dose assessment. The need to notify other persons, such as regulatory authorities, should be included in the plans.

4.1.3 Training in emergency plans

The emergency plans should be brought to the attention of all relevant persons, and they should receive instruction and training in respect of the roles they are expected to undertake. Each radiographer and RPO should have personal copies of the plan.

In addition, the emergency procedures set out in the plans should be rehearsed at least once a year. This should help to reinforce the responsibilities allocated to individuals, and provide valuable practice in techniques such as source recovery (using dummy sources). The participation of individuals in such rehearsals should be recorded.

4.2 Dealing with Non-retracting Gamma Sources

Many radiography incidents have been due to either to a source failing to return properly (i.e. to a projection-type exposure container) at the end of an exposure, or to a source becoming separated during or after use. Because of this, some specific guidance is given below on the actions to be followed in the event of such an incident occurring. The underlying principles (i.e. cease work, restrict access, plan the recovery) are, however, applicable to other types of radiography incident.

4.2.1 Action by Radiographer/RPO

- Stop any radiographic work, but maintain any existing exposure warnings.
- Prevent access to the area. If the incident gives rise to increased dose rates, the barriers and warning notices should be repositioned. The area should not be left unsupervised.
- Only trained radiography personnel should be engaged in source recovery operations. Other persons who may have been inside the newly barriered area should be interviewed.
- **Plan** a course of action, before entering the barriered off area. This should include collecting emergency equipment, and estimating the doses that are likely to be received.
- Inform the client what has happened and what action is proposed.
- Implement the planned course of action.
- if possible, a separated source should be returned to the original container, or else placed in a special emergency container. Use should be made of emergency equipment such as long-handled (up to 2 metres) tongs, keeping at arm's length. Sources should **never** be picked up with bare hands.
- The operation should first be practised outside the area to ensure that it can be done quickly - a second person should stand at the barrier to time the operation, and indicate when the recommended time has expired. A dose-rate meter should be used to check that the source is back in the container.
- If it cannot be replaced in the container, local shielding (e.g. bags of lead shot) should be placed over the source. Again, care should be taken to keep all parts of the body at arm's length from the source. Once local shielding has been placed, this may allow closer access, for example:
  - to remove obstructions (i.e. to facilitate the retraction of the source); or
  - to allow the source to be freed from the wind-out mechanism (i.e. to enable it to be placed in a shielded container, as described above).
- Call for specialist assistance via the RPE if the source cannot be retrieved.

4.2.2 Follow-up Action by RPO

If the source has been returned to the container the following action should be taken:

- Check the shielding and the fastenings of the container, and place the container in a suitable store;
- Arrange for dose assessment for the radiographers and other persons involved in the recovery operation;
- Notify the relevant authorities, as required by the national regulations;
- Make a full investigation of the circumstances. This should include taking written statements from radiographers, details of where they were in relation to the source and for how long. Similar information should be obtained from any other persons or members of the public who may have been exposed to radiation.