

LEAFLET 28**INDUSTRIAL RADIOGRAPHY INCLUDING ENCLOSURES, SITE AND UNDERWATER RADIOGRAPHY****CONTENTS****Para**

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SCOPE

- 1 Industrial radiography applications in MOD include:
 - 1.1 Radiography in enclosures using both high activity sealed radioactive sources (HASS) and X-ray generators;
 - 1.2 Site radiography using high activity sealed sources or X-ray;
 - 1.3 Underwater radiography using high activity sealed sources;
 - 1.4 X-ray equipment used may be continuous, flash or pulsed.

2 This leaflet describes the radiological requirements for these types of radiography and includes the keeping, using and disposing of radioactive sources and equipment used in radiography. Summaries of the radiation risk and regulatory requirements are provided in the main body and the annexes of this leaflet. The RPA must always be consulted prior to any new activity or change in activity associated with industrial radiography.

3 The scope of this leaflet does not extend to the use of accelerators. The scope of this leaflet does not extend to the use of X-ray or radioactive sources for instrument testing, security scanning nor does it extend to the use of X-ray for the processing of products, research, medical treatment, medical diagnosis or for dental and veterinary applications.

STATUTORY REQUIREMENTS AND PARALLEL ARRANGEMENTS

4 In addition to the general requirements of the Health and Safety at Work etc Act 1974 and the Management of Health and Safety at Work Regulations 1999, the following specific legislation applies directly or is applied indirectly through parallel arrangements designed to achieve equivalent standards:

- Ionising Radiations Regulations 1999 (IRR99) (apply directly);
- Radioactive Substances Act 1993 (RSA93) (parallel arrangements);
- The High-activity Sealed Radioactive Sources and Orphan Sources Regulations 2005 (parallel arrangements);
- Carriage of Dangerous Goods and Transportable Pressure Equipment Regulations 2007 (apply directly);
- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (apply directly).

DUTIES AND APPOINTMENTS

Commanding Officer and Head of Establishment (CO/HoE)

5 The CO/HoE has a duty to the Secretary of State, and a personal responsibility, to protect the environment and secure the health, safety and welfare of their staff at work. The CO/HoE is also required to protect persons not in MOD employment (e.g. members of the public) against risks to their health and safety arising from the MOD work activities. This includes radiation safety. The CO/HoE's authority (but not responsibility) for radiation safety management arrangements may be delegated to appropriate personnel, such as a Radiation Safety Officer (RSO).

Radiation Safety Officer (RSO)

6 The Radiation Safety Officer (RSO) is to ensure that:

- On behalf of the CO/HoE, that a suitable RPA has been appointed and that the RPA is consulted prior to acquisition of radioactive sources or X-ray equipment and prior to any work commencing which involves industrial radiography each and every time;
- They are familiar with the specific radiation hazards of industrial radiography at their unit or establishment and that appropriate risk assessments are carried out before any new activity (or change in an existing activity) involving industrial radiography is commenced;
- Local orders include the specific requirements for the industrial radiography carried out;
- Staff are suitably qualified and experienced prior to them undertaking any industrial radiography work and that this process is documented;

- Staff competency is closely monitored, including the need for continuation training and recertification;
- Quality assurance requirements relating to industrial radiography are strictly adhered to, an audit programme is in place and audit recommendations are followed up and documented.

Radiation Protection Adviser (RPA)

7 A suitable RPA must be appointed in writing and consulted prior to the acquisition of industrial radiography equipment and prior to commencing any industrial radiography work. For all units and establishments, other than those with a resident RPA, the RPA will normally be provided by the Dstl RPA Body.

Radiation Protection Supervisor (RPS)

8 The RPS is to ensure that work is carried out in designated controlled areas in accordance with the local radiation safety orders for industrial radiography. These orders must include the requirements of *local rules* (as required by IRR99) and the requirements of this Leaflet.

Employees

9 It is the responsibility of all employees to ensure that they are familiar with the relevant parts of local orders to ensure that industrial radiography work is carried out safely. Regulations also require employees to comply with any reasonable requirement in regard to the following:

9.1 Their dose assessment;

9.2 Their medical surveillance;

9.3 Reporting of any loss or release of radioactive material (report to supervisor);

9.4 Reporting (to supervisor) of any failure of industrial radiography equipment to de-energise or return to its safe position after the intended exposure period.

TYPICAL GAMMA AND X-RAY SOURCES USED IN INDUSTRIAL RADIOGRAPHY

10 Table 1 lists the main types of source used in MOD together with typical activities, half life and associated dose or dose rate.

Table 1 Data for typical gamma and X-ray sources used in industrial radiography within MOD

Radionuclide	Typical Maximum Activity (TBq)	Energy (keV)	Half Life	Typical maximum dose or dose rate at 1m
Cobalt-60 (Co-60)	4	1170; 1330	5 years	Approx 1.2 Sv h ⁻¹
Iridium-192 (Ir-192)	7	210-610	74 days	Approx 800 mSv h ⁻¹
Caesium-137 (Cs-137)	0.5	660	30 years	Approx 40 mSv h ⁻¹
X-ray Generator (continuous)	N/A	Up to 300	N/A	Up to >10 Sv h ⁻¹
X-ray generator (flash)	N/A	Up to 1000's	N/A	Up to >10 Sv per flash
X-ray generator (pulsed)	N/A	Up to 300	N/A	Up to 10 µSv per pulse

HAZARDS

Table 2 Hazards associated with industrial radiography sources and X-ray generators

Radiation type		Emitted	Comments
Alpha		✗	Alpha radiation is not normally emitted by radioactive sources used in industrial radiography and would be absorbed by the source capsule.
Beta	Direct	✗	Although most radioactive sources used in industrial radiography are beta emitters, design is such that beta radiation is absorbed by the source capsule. Sources are normally designed as special form sealed sources thus making it extremely unlikely that beta emitters could be released and cause an internal hazard.
	Bremsstrahlung	✗	Levels of bremsstrahlung radiation (X-rays) are insignificant compared with gamma levels from the radioactive sources used in industrial radiography.
Gamma		✓	Gamma radiation is emitted by radioactive sources used in industrial radiography. Such sources are high-activity sealed sources – dose rates at ~ 1 m of an unshielded source could lead to whole body overexposure levels in minutes. An exposure of a few seconds in closer proximity to a source could be sufficient to initiate irreversible deterministic effects such as tissue damage.
X-rays		✓	X-ray generators used in industrial radiography generate in-beam dose rates which could lead to overexposure levels in seconds. Significant (leakage) dose rates can also occur in out of beam areas around the X-ray set. Pulsed X-ray equipment gives lower in-beam time averaged dose rates due to the limited number of very short duration pulses of X-rays which are used to produce a radiograph. Flash X-ray equipment may operate at very high energy and high power giving rise to potentially lethal in beam dose levels.
Neutrons		✗	Neutron sources are not currently used within MOD for industrial radiography.

RISK ASSESSMENTS

11 In the acquisition of equipment emitting ionising radiation, safety and environmental management is to begin at the requirements definition stage and is to be carried forward through service to disposal. All aspects of maintenance and operation (including military service) are to be taken into account and particular care is to be given in assessing risk and environmental impacts where there is no appropriate statute or comparative civil practice. Prior risk assessments are a statutory requirement before the commencement of any industrial radiography. Although generic information provided by manufacturers, IPTs and this publication may be useful as input to these assessments, these are not, in themselves, sufficient and considerations specific to the type of work and enclosure to be used must be included. It is a statutory requirement that the RPA is consulted regarding a number of aspects (see Table 3). Leaflet 2 gives further general instruction and guidance on the components of a prior risk assessment.

12 Recommendations for dose restriction arising from the risk assessment must be adopted, unless, following advice from the RPA, other effective alternative solutions are available.

TRAINING

Note: The following training requirements are not applicable to EOD operators using pulsed x-ray equipment. Specific training requirements for EOD operators using pulsed x-ray equipment are given at annex E to this leaflet.

13 The RPS and the radiographers are to be formally trained and certificated in radiography and are to be formally instructed in the use of each type of radiographic equipment that they are to operate. Radiographers are to be trained to Personal Certification in Non-Destructive Testing (PCN) Level 1 (or equivalent) and the RPS to PCN level 2 (or equivalent) (see below).

14 The RPS is to be familiar with the following publications, in addition to IRR99 and the associated Approved Code of Practice:

14.1 Radiation Protection Supervisors IRIS6 HSE 2000 www.hse.gov.uk/pubns/irp6.pdf;

14.2 Personnel Certification in Non-Destructive Testing (NDT) – General Information e.g. www.bindt.org/mk1site/PCN.html;

14.3 HSE Information Sheet – Industrial Radiography – managing radiation risks www.hse.gov.uk/pubns/irp1.pdf.

15 Records are to be maintained of the training undertaken. Persons assisting radiographers are to be instructed in the actions that they are to take before commencement of radiography. They are also to be instructed in the actions to be taken in the event of an incident or accident involving the radiographic equipment.

LEGAL AND MOD MANDATORY REQUIREMENTS

16 Table 3 below summarises the legal and MOD mandatory requirements for industrial radiography using both high-activity sealed radioactive sources and X-ray generators. Consultation with the RPA is advisable for all aspects of this work and is a statutory requirement in a number of areas as indicated below.

17 Further guidance on the radiation safety arrangements for industrial radiography in enclosures; for site radiography; for underwater radiography; and for flash/pulsed X-ray equipment is given at Annexes B to E respectively.

Table 3 Legal and MOD mandatory requirements for industrial radiography

Requirement	Applicable	Comments	Related leaflet*
HSE authorisation of specified practices (X-ray generators)	✓	Prior authorisation is required for the use of electrical equipment to generate X-rays for industrial radiography. HSE has issued a generic authorisation (see Annex A to Leaflet 3) which can be used provided that the conditions of the generic authorisation are met. Any planned use of the equipment for other purposes may require an individual prior authorisation	3
HSE authorisation of specified practices (radioactive sources)	✗	Not required	
HSE notification (X-ray generators and radioactive sources)	✓	Notification is required in accordance with Leaflet 3. Re-notification is required if there is to be any material change in the type of work carried out. HSE may require notification prior to each occasion on which radiography is carried out – however employers are exempt from this requirement for work carried out for or on behalf of MOD.	3
EA notification** (X-ray generators)	✗	Not required.	

Table 3 Legal and MOD mandatory requirements for industrial radiography (continued)

Requirement	Applicable	Comments	Related leaflet*
EA notification** (radioactive sources)	✓	Radioactive sources used for industrial radiography are likely to be mobile high-activity sealed sources (HASS). Prior notification to EA to hold HASS placed on the market on or after 1 January 2006 is required by operators in accordance with Leaflet 3. HASS placed on the market on or before 31 Dec 2005 continued to be held under existing arrangements. These transitional provisions expired on 31 Dec 2007 and operators were required to apply for new permits at least 4 months in advance of this date.	-
Risk assessment (X-ray generators and radioactive sources)	✓	A prior risk assessment must be carried out prior to any new activity involving work with ionising radiation (see Leaflet 2).	2
Restriction of exposure (X-ray generators and radioactive sources)	✓	The external radiation hazard is very high and the primary means of restricting exposure must be by means of engineering controls and design features (e.g. shielding and beam collimation). This is to be supplemented by the provision of safety features (e.g. locks on exposure controls, door interlocks for enclosures, emergency off buttons) and warning devices. Finally, systems of work which prevent access to enclosures or controlled areas during irradiation must be in place. Where reasonably practicable, radiography is to be carried out in a purpose made enclosure. Consultation of an RPA is a statutory requirement with respect to prior examination of plans for new or modified sources of radiation in relation to engineering controls, design features, safety features and warning devices. Also the RPA must be consulted regarding the testing of same and to check that systems of work are adequate to restrict exposure.	4 (general requirements)
Maintenance of radiation engineering controls (X-ray generators and radioactive sources)	✓	Radiation employers must ensure that engineering controls, design features, safety features and warning devices are properly maintained and tested at suitable intervals. Statutory requirement for RPA consultation as above.	4
PPE (X-ray generators and radioactive sources)	✗	Not required – significant attenuation of high energy X-ray or gamma radiation cannot be practicably achieved by any form of protective clothing.	
Contingency plans (X-ray generators and radioactive sources)	✓	Plans for reasonably foreseeable radiation accidents must be included (or referred to) in local orders; plans must be rehearsed and employees must be given suitable instructions.	40
Designated areas (X-ray generators and radioactive sources)	✓	Designated areas (e.g. controlled and supervised radiation areas) are necessary for all types of industrial radiography work. Leaflet 4 provides further instruction and guidance.	4

Table 3 Legal and MOD mandatory requirements for industrial radiography (continued)

Requirement	Applicable	Comments	Related leaflet*
Monitoring (X-ray generators and radioactive sources)	✓	Monitoring of designated areas (see Leaflet 4) and surrounding areas is required using appropriate instruments (see Leaflet 8). It is a statutory requirement that the RPA be consulted regarding calibration and checking of equipment provided for monitoring levels of ionising radiation. Survey records are to be kept for at least 2 years.	4, 8
Training (X-ray generators and radioactive sources)	✓	Training and qualification of all supervisors and operatives is essential prior to carrying out any radiography.	15
Local orders (X-ray generators and radioactive sources)	✓	Provision of written <i>local rules</i> is a statutory requirement – these may be encompassed within local orders - see Leaflet 16 for guidance.	16
Appointed person (X-ray generators and radioactive sources)	✓	An RPS is required to ensure work is carried out in accordance with the <i>local rules</i> . Appointment to be made in accordance with Leaflet 39.	39
Storage (X-ray generators and radioactive sources)	✓	Radioactive sources are to be installed in lockable containers where they can be safely and securely stored when not in use. Further guidance on storage and security is provided at the annexes and at Leaflet 9. HASS source security requirements will be issued separately. Facilities for X-ray equipment are to provide a lock-off arrangement in a physically secure and weatherproof environment.	9
Accounting (X-ray generators and radioactive sources)	✓	Radioactive sources are to be accounted for in source lists in accordance with Leaflet 9. Sources used in industrial radiography are subject to the requirements of the HASS regulations and records are required to be submitted to EA periodically in accordance with the terms and conditions for MOD users. Details of both sources and generators are to be provided on the Dstl Annual Holdings Return, copy retained for 1 year.	9
Leak testing (radioactive sources)	✓	Leak testing is to be carried out at intervals not exceeding 2 years. RPA advice is to be sought on the frequency and the most appropriate test method. A leak test is to be carried out following any accident involving possible damage to a radiography source.	9
Classified persons (X-ray generators and radioactive sources)	✓	Radiographers and the RPS must normally be designated as classified persons (see Leaflet 4 and the annexes to this leaflet). Classified persons are to be provided with an annual health review to determine suitability to continue radiation work.	4

Table 3 Legal and MOD mandatory requirements for industrial radiography (continued)

Requirement	Applicable	Comments	Related leaflet*
Personal dosimetry (X-ray generators and radioactive sources)	✓	Classified persons must be provided with and wear appropriate dosimetry issued by an Approved Dosimetry Service. A radiation passbook must be raised for each classified person. In addition to the approved dosimeter, day to day monitoring of radiation dose for radiographers should normally be effected by the wearing of a suitable personal integrating electronic dosimeter providing audible alarms at predetermined dose rates and integrated doses.	6
Reporting procedures (X-ray generators and radioactive sources)	✓	All losses and certain other unusual radiation events require to be reported to MOD authorities and external regulatory authorities in accordance with Leaflet 14. Note: this includes failure of a radiographic source to retract or an X-ray set to de-energise.	14
Transport (radioactive sources)	✓	Radiography sources must generally be transported in approved Type B containers. Transport must be in accordance with JSP 800 Vol. 4b for road, rail and sea transport or JSP 800 Vol. 4a for air transport. Movement of sources on site must be carried out under written procedures in accordance with Leaflet 10.	JSP 800 Vol. 4a & Vol. 4b and Leaflet 10
Marking (X-ray generators and radioactive sources)	✓	Marking of items, equipment and containers is to be in accordance with Leaflet 9 and marking of designated areas in accordance with Leaflet 4. Further guidance is at the annexes to this leaflet.	9, 4
Disposal of redundant items (X-ray generators and radioactive sources)	✓	Disposal of high-activity radioactive sources must comply with the requirements of the HASS regulations and be in accordance with the terms and conditions for MOD users supplied by EA. (See also Leaflet 12). Arrangements for management of disused sources and financial provision for their disposal must be made before acquiring such sources. X-ray generators are normally to be disposed of via an appropriate manufacturer. Further guidance on disposal is at the annexes to this leaflet.	12

*JSP 392, unless otherwise stated

**Environment Agency (EA) for England and Wales, Scottish Environment Protection Agency (SEPA) for Scotland and Environment and Heritage Service for Northern Ireland (EHSNI).

RADIOACTIVE SEALED SOURCES AND THEIR CONTAINERS

18 Detailed guidance on the requirements for industrial radiography radioactive sealed sources and their containers is at Annex A.

PHYSICAL SECURITY ARRANGEMENTS FOR HIGH-ACTIVITY SEALED RADIOACTIVE SOURCES

19 Radiography facility managers are to be aware of the contents of Security Requirements for Radioactive Sources issued by the National Security Advice Centre. Copies of this document are available from the Counter Terrorism Security Adviser (CTSA) or the Dstl RPA Body. Advice on application of this guidance is to be sought from the appropriate Principal Security Adviser.

CONTRACTORS

20 Where contractors are employed to undertake radiography at a unit or establishment, they are to work in accordance with the requirements of the IRR99 and the Approved Code of Practice. All contractors undertaking radiography on a MOD site are to meet the strict safety requirements attaching to such work, including the requirements of this Leaflet, to the satisfaction of the CO through the RSO and/or RPS. Details of general contractor control arrangements are given in JSP 375.

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LEAFLET 28 ANNEX A**REQUIREMENTS FOR RADIOACTIVE SEALED SOURCES AND THEIR CONTAINERS****CONTENTS****Para**

- 1 Radioactive sources and containers
- 9 Loading and unloading of radioactive sources
- 12 Physical security at sites holding high activity radioactive sources

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- A1 Maximum dose rate limits for exposure containers.....2

RADIOACTIVE SOURCES AND CONTAINERS

1 Every radiography source is to have a unique means of identification, and no source is to be used without a valid leakage test certificate. The source is to be installed in a container where it can be securely stored when not in use. New exposure containers are to conform to ISO 3999:2004. If these containers are to be transported, they are also to meet current transport regulations detailed in JSP 800 Vol. 4b. All exposure containers are to be permanently and indelibly marked (possibly by fitting with a metal plate) with the following information:

1.1 The radiation trefoil;

1.2 The word RADIOACTIVE in letters not less than 10 mm high;

1.3 The maximum rating of the container, for example an Iridium-192 source with a maximum container rating of X Bq would be shown as:

1.3.1 Rating X Bq Ir-192;

1.4 The manufacturer, type and serial number;

1.5 The mass of the exposure container if it is Class P, M or F as described below.

2 The following durably marked information is to be attached to the exposure container:

2.1 Chemical symbol and mass number of radionuclide, for example, Ir-192;

2.2 Activity and date activity was measured;

2.3 Identification number of sealed source.

3 ISO 3999:2004 classifies source containers according to their mobility. The classification is described as follows:

3.1 Class P: A portable exposure container, designed to be carried by one man alone;

3.2 Class M: A mobile but not portable exposure container, designed to be moved by a suitable means provided for that purpose;

3.3 Class F: A fixed installed exposure container or one with mobility restricted to the confines of a particular area.

Dose rate limits for these containers are given in Table 1.

Table A1 Maximum dose rate limits for exposure containers (in $\mu\text{Sv h}^{-1}$)

Class	External surface of container	50 mm from external surface of container	1 m from external surface of container
P	2000	500	20
M	2000	1000	50
F	2000	1000	100

4 If the exposure container has a shutter, an indication of its status, whether open or closed, must be clearly indicated on the exposure container.

5 Every exposure container is to be provided with a lock to prevent unintended or unauthorised exposures. The lock is to be designed so that if it becomes defective it will not prevent retraction of the source. The act of unlocking the container must also not give rise to immediate exposure of the source.

6 Additional requirements for High Activity Sealed Sources placed on the market on or after 1 Jan 2006 include the engraving or stamping of a unique number on the source (where feasible) and container and the provision by the manufacturer of a photograph of the source type and typical source container. Holders are required to ensure that each source is accompanied by written information. These provisions, where practicable, will also apply to existing sources (placed on the market before 1 Jan 2006) and containers from 1 Jan 2008.

7 The source container when not in use must be kept locked and, unless the source is stored in an automatic exposure device and interlocked to the entrances to the enclosures, is to be stored in a radioactive source store which is designated a controlled radiation area. The store is to be physically secure and marked at the entrance with a radiation warning sign including details of the radioactive sources and the risks arising from these sources. Sufficient shielding is to be provided to ensure that persons outside the store will not receive a dose exceeding 1 mSv in a year. In practice this will normally be achieved by ensuring that the radiation dose rate at any point on the outside walls of the building is less than $1 \mu\text{Sv h}^{-1}$. Arrangements are to be made for the keys of the store to be kept in a secure place and the number of persons authorised to draw them kept to a minimum compatible with operational requirements.

8 For short term exercises, where sources are used away from their base locations, it is acceptable for sources to be stored in their source container and transport packaging, in a locked and placarded vehicle in a secure area. For sources subject to HASS regulations, the conditions on the notification certificate must be applied.

9 Exposure containers must be inspected and maintained in accordance with the manufacturer's or supplier's recommendations.

LOADING AND UNLOADING OF RADIOACTIVE SOURCES

10 Source assemblies used for radiographic examinations are only to be loaded into containers which are compatible with the type of assembly to be installed.

11 Changing of sealed sources will often be undertaken by the source manufacturer or their agent. Where this is not the case and the changing of sources is undertaken by the establishment it will be necessary to introduce a set of administrative controls and procedures to ensure that doses are kept as low as reasonably practicable. This will normally be achieved by using specially designed transfer equipment within a controlled area and will take the form of a system of work drawn up by the establishment, in consultation with the RPA. The system of work is to include the names of persons who may undertake the work under supervision.

12 Persons undertaking this work are to be adequately trained and experienced. The procedure is to be rehearsed using a dummy source to ensure that it can be carried out quickly and safely.

PHYSICAL SECURITY AT SITES HOLDING HIGH ACTIVITY RADIOACTIVE SOURCES

13 Physical security at the site where the radioactive sources are normally stored is to be designed to accord with the principles described in the publication Security Requirements for Radioactive Sources issued by the National Security Advice Centre. Advice on the use of this document is to be sought from the Principal Security Adviser who is also to be approached for advice on the level of security appropriate for occasional storage at the client site.

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LEAFLET 28 ANNEX B**GUIDANCE ON RADIATION SAFETY ARRANGEMENTS
FOR INDUSTRIAL RADIOGRAPHY IN ENCLOSURES****CONTENTS****Para**

- 1 Introduction
- 2 Designation of radiography enclosures
- 7 Access to radiography enclosures
- 8 Design of enclosures
- 19 Warning devices
- 28 Operating procedures

INTRODUCTION

1 The main body of this leaflet details the general statutory and MOD mandatory instruction for radiation safety in industrial radiography. This Annex, which must be read in conjunction with the main body of the leaflet provides **additional** guidance specific to the radiation safety arrangements for industrial radiography undertaken in enclosures. Such radiography involves the generation of intense beams of radiation emitted from high-activity sealed sources or from X-ray generators. High-activity sealed sources used in radiography are capable of delivering overexposure levels of dose at 1 m in minutes whereas an overexposure from an X-ray generator at the same distance could occur in seconds.

DESIGNATION OF RADIOGRAPHY ENCLOSURES

2 The designation of radiographic enclosures as controlled areas during the exposure of radiographic sources or the operation of an industrial X-ray set is to be undertaken in consultation with the RPA.

3 Suitable controlled radiation areas signs (see Leaflet 4), detailing the nature of the radioactive source and the risks arising from the source, are to be displayed around the perimeter of the controlled area and at each entrance to the enclosure.

4 Suitably worded signs are to be posted on each outside wall of the radiation enclosure to warn, where appropriate, against access to the roof without the permission of the RPS.

5 Where radiographic sources are used, the radioactive source store will be a controlled radiation area. The store is to be appropriately marked and display a sign on the door listing the radioactive contents within the store and the risks arising from the sources held.

6 All controlled and supervised areas are to be suitably described in local orders.

ACCESS TO RADIOGRAPHY ENCLOSURES

7 Entry to the radiography enclosure is prohibited during radiation exposure other than in special circumstances under a permit-to-work (see Leaflet 4) such as in returning a radiographic source to its container when it cannot be returned from outside the enclosure. All such special procedures are to be undertaken in consultation with the RPA.

DESIGN OF ENCLOSURES

8 Enclosures for industrial radiography using radioactive sealed sources or X-rays must provide sufficient shielding to reduce the radiation dose rate to $7.5 \mu\text{Sv h}^{-1}$ at any point on the surface of the outside wall of the enclosure. Additional shielding is to be provided for facilities in constant use. New facilities are to be designed, where reasonably practicable, to provide sufficient shielding such that the external dose rate will not exceed $1 \mu\text{Sv h}^{-1}$.

9 Control panels for X-ray machines or radioactive sources must be situated outside the walled enclosure.

10 Where an X-ray machine is used, interlocks are to be provided and maintained to ensure that should any door to the enclosure be opened while an X-ray machine within it is energised, the machine will be automatically de-energised and cannot be operated so long as that door remains open.

11 Where a radioactive sealed source is used, where reasonably practicable, interlocks are to be provided and maintained at all entrances to an enclosure, such that while a sealed source is exposed no door to the enclosure can be opened, and that a sealed source cannot be exposed while any door is open.

12 Where an interlock has been opened, a radiographic exposure is not to re-start simply by remaking the interlock. It must be necessary to re-set the interlocks and the operator must go through the re-start sequence at the control point before the X-ray machine or sealed source can be exposed.

13 All interlocks are to be designed and positioned so that they cannot easily be interfered with, and are to be of a fail-safe type.

14 Interlocks are to be regularly examined and tested at a frequency laid down in the local orders. Records of such tests are to be maintained, to identify the tests carried out, any actions required to maintain the interlocks and the date the next examination is due.

15 For the protection of persons accidentally shut inside an enclosure, an alarm is also to be provided to summon help from outside the enclosure. In addition, in all X-ray facilities and, where reasonably practicable, sealed source radiography, a means of controlling the radiation source from inside the room is to be provided. Such a control is to prevent exposure from taking place if activated outside the exposure phase, and terminate if operated during an exposure. A sufficient number of prominently marked controls (stop buttons or pull cords) are to be provided such that they may be activated promptly and without crossing a main exposure beam. These controls are to be of a type that needs to be positively re-set from the location at which they were operated before further exposures may be initiated. Such devices are to be regularly tested and documented. If it is not reasonably practicable to control the sources from inside the room, a shielded refuge is to be provided inside the enclosure. The RPA must be consulted about the design of this refuge.

16 A prominent notice is to be displayed in the enclosure explaining the actions to be taken in the event of being accidentally shut inside the enclosure.

17 Where manually operated source wind out systems are used, or where the dose rate exceeds 50 mSv min^{-1} at 1 m from the source, a search-and-lockup system is to be provided and operated before each exposure, to ensure that no-one may be accidentally shut inside at the beginning of an exposure.

18 Where an enclosure has been designed such that there are limitations on the positioning of the radiography source or the X-ray machine within the enclosure, the equipment operating area is to be clearly marked.

WARNING DEVICES

19 Adequate warning to all persons in the vicinity is to be given by appropriate visual or audible signals, or both:

- 19.1 When a sealed source is about to be exposed, or when an X-ray machine is about to be energized (pre-exposure warning alarm);
- 19.2 While a source is exposed or an X-ray machine is energised (continuous exposure warning alarm).
- 20 The duration of the pre-exposure warning alarm is to be sufficient for anyone accidentally shut inside the enclosure to take appropriate action.
- 21 The pre-exposure warning alarm must be easily distinguishable from the continuous exposure warning alarm and both warnings must be clearly explained on well sited signs. To achieve this, a warning signal may be combined with a sign in the form of an illuminated sign.
- 22 In the case of X-ray machines, and sealed sources capable of producing $>10 \text{ mSv min}^{-1}$ at a distance of 1 m, the warning signals and illuminated signs are to be arranged to operate automatically.
- 23 Warning signals are to be installed inside the enclosure and outside each entrance to the enclosure.
- 24 A further exposure warning signal (such as a red light) is to be activated on the control panel and is to remain on long enough for the indication to be seen by the operator irrespective of the exposure duration.
- 25 Warning devices for X-ray enclosures are to be fail-safe, i.e. if the warning device fails the exposure will not proceed. If reasonably practicable, warning devices for sealed source enclosures are to be fail-safe.
- 26 All warning signals are to be regularly examined and tested to ensure their satisfactory operation. Records of such checks are to be maintained, to identify the tests carried out, any actions required to maintain the interlocks and the date the next examination is due.
- 27 Explanatory notices are to be provided to inform employees and other persons as to the purpose of the warning signal.

OPERATING PROCEDURES

- 28 Work involving the exposure of sealed sources or operation of an X-ray set is only to be undertaken in accordance with local orders, including local rules and written arrangements. drawn up by the establishment in consultation with the RPA (see Leaflet 16). Unclassified persons are only to enter a controlled area under written arrangements (see Leaflet 5).
- 29 The movement or manipulation of sealed sources is to be undertaken by remote control. Radiographic sources must never be handled with bare or gloved hands.
- 30 The radiography set-up is to be completed before the X-ray machine is energized or the sealed source is exposed. No material is to be brought into the radiation beam except by the use of mechanisms operated from outside the enclosure.
- 31 Where there are limitations on the location of these equipments inside the enclosure, the radiography source or the X-ray machine is only to be operated in the demarcated area
- 32 Before an X-ray machine is operated, or a sealed source is exposed, a search of the enclosure is to be made to ensure that no one has been accidentally shut inside.
- 33 After each exposure, personnel approaching the source must do so with a dose rate monitoring instrument to verify that the X-ray machine has de-energized or that the source has retracted fully home into its container. Where practicable, suitable electronic alarming dosimetry should also be worn.

34 The dose rate outside an enclosure is to be checked regularly and particularly after any change of radiation source or methods of work. The results are to be recorded in a survey report which is to be retained for a period of at least 2 years from the date of completion.

35 All radiation protection and monitoring instruments used in radiographic work are to be calibrated and tested in accordance with the requirements detailed in Leaflet 8.

LEAFLET 28 ANNEX C**RADIATION SAFETY ARRANGEMENTS FOR SITE RADIOGRAPHY****CONTENTS****Para**

- 1 Introduction
- 2 Co-operation between units
- 4 Appointments
- 5 Storage of radiography sources
- 6 Controlled areas
 - Equipment requirements
- 11 X-ray apparatus
- 12 Sealed sources
- 13 Warning signals
- 19 Precautions with high output machines
- 20 Operating procedures
- 29 Monitoring surveys
- 30 Radiography safety audits
- 31 Emergency procedures

INTRODUCTION

1 The main body of this leaflet details the general statutory and MOD mandatory instruction for radiation safety in industrial radiography. This Annex, which must be read in conjunction with the main body of the leaflet provides **additional** guidance specific to the radiation safety arrangements for site radiography. Such radiography involves the generation of radiographs using radiation emitted from high-activity sealed sources or from X-ray generators. High-activity sealed sources used in radiography are capable of delivering overexposure levels of dose at 1 m in minutes whereas an overexposure from an X-ray generator at the same distance could occur in seconds.

CO-OPERATION BETWEEN UNITS

2 Prior to site radiography taking place the RSO, or other person(s) nominated by the RSO, such as an engineering officer or facility manager at the unit or establishment where radiography is to be undertaken is to be supplied with the following information by the Officer Commanding the Non-Destructive Testing (NDT) team:

- 2.1 Prior notification and permission for the NDT source or X-ray machine to be brought on site;
- 2.2 Name of RPAs and RPSs and how they can be contacted on or off site;
- 2.3 Places where work will be carried out including dates and description of work procedures and work instructions;
- 2.4 Details of radioactive sources or X-ray machines to be used;
- 2.5 For sources only, their stowage requirements including both safety and security aspects;
- 2.6 Description of monitoring procedure;
- 2.7 Risk assessments and contingency plans;
- 2.8 Details of methods of transportation of sources;

2.9 Health and Safety policy statement containing radiography local orders and procedures for the radiographers.

3 For repeated site radiography examinations undertaken at the same unit or establishment the RSO may agree with the officer commanding the NDT team to receive a single notification of those elements above that do not frequently change. After the initial notification the officer commanding the NDT team will be required to resubmit the notification to the unit's / establishment's RSO for their approval annually, when there is a change to the RSO or whenever there is a change to these details. In addition, those elements above that do change frequently are to be supplied to the RSO or other appropriate person, each time before radiography is undertaken at the unit or establishment.

APPOINTMENTS

4 Site radiography requires a number additional factors to be considered regarding the appointment of suitably qualified and experienced staff as follows:

4.1 An RPS is to be appointed in writing by the CO for site radiography undertaken within an establishment and for the storage of radiographic sources in a source store;

4.2 Sufficient RPSs are to be appointed in writing by the CO so that whenever radiography is undertaken outside an establishment, or at another establishment, it is undertaken under the direct supervision of an RPS. The RPS is responsible for ensuring that radiation doses are kept as low as reasonably practicable for not only personnel involved in the radiography but for all other persons who may receive radiation doses from the radiography;

4.3 All RPSs who undertake supervision of site radiography are to be trained in accordance with the requirements of this leaflet and Leaflet 15. The training is to specifically include radiation safety arrangements for site radiography;

As well as the general duties of an RPS, the RPS is to ensure that:

4.4 All personnel directly involved in, or who may be affected by, the radiography are aware that such work is going to take place;

4.5 Verbal contact is maintained with all relevant personnel while radiography is taking place;

4.6 All equipment and services are compatible and in working order;

4.7 No other work or conflicting activities takes place in the vicinity which could adversely affect the safety any person or the radiographic set-up.

STORAGE OF RADIOGRAPHY SOURCES

5 If it is necessary for a radiographic sealed source to be stored on the site, it must be stored in accordance with the general requirements of Leaflet 9 and, in addition, for high-activity sealed sources, the security arrangements for the store must be adequate – in case of doubt the appropriate Principal Security Adviser is to be consulted. Suitable radiation warning signs are to be posted on the store, with the name and telephone number of the RPS and details of the source. A written system of work agreed with the RPA is to be made available to the CO/HoE and the RSO at the establishment and such personnel that may be affected by its storage (e.g. security and cleaning staff and the site fire officer).

6 For short term exercises, where sources are used away from their base locations, it is acceptable for sources to be stored in their source container and transport packaging, in a locked and placarded vehicle in a secure area. For sources subject to HASS regulations, the conditions on the notification certificate must be applied.

CONTROLLED AREAS

7 A controlled area is to be set up before any radiographic exposure is undertaken outside an enclosure. The extent of the controlled area is to fulfil the following, unless otherwise advised by the RPA :

7.1 Within an establishment, all areas outside the controlled area are to be at dose rates (averaged over one minute) of less than $7.5 \mu\text{Sv h}^{-1}$. In public places barriers and signs are to be set up where dose rates exceed $2.5 \mu\text{Sv h}^{-1}$.

7.2 The extent of controlled areas is to be determined in consultation with the RPA, initially by calculating the appropriate distance from the source to the $7.5 \mu\text{Sv h}^{-1}$ dose rate contour within an establishment or the $2.5 \mu\text{Sv h}^{-1}$ dose rate contour in public places. On exposure of the sealed source or the X-ray machine, dose rate measurements are to be taken and the barrier moved until the dose rates do not exceed $7.5 \mu\text{Sv h}^{-1}$ or $2.5 \mu\text{Sv h}^{-1}$, as appropriate.

7.3 It is to be set up so that access control can be effectively achieved. Access to controlled areas is to be restricted by the use of barriers, fixed structures, (such as the walls of buildings or bulkheads of ships).

7.4 It is to be minimised by utilising local shielding such as walls, beam collimation etc.

8 No one is to work inside the area until the site radiographic exposures are complete. However, subject to the provisions of local orders, where it is unavoidable for the purposes of initiating or terminating an exposure, personnel may enter the controlled area provided they are not exposed to an instantaneous radiation dose rate in excess of 2 mSv h^{-1} .

9 Where radiography is undertaken in a multi-storey building or on board ship, the controlled area is not only to include areas on the same level, but where appropriate, levels above and below the source of the radiation emission are to be designated as controlled areas.

10 Suitable warning signs (see Leaflet 4) are to be displayed at appropriate points around the perimeter of the controlled areas, such that a person approaching the controlled area from any direction would be made aware of the hazard. The signs are to state that the area is a controlled area and give details of the radiation hazard and the risks arising from the radiation source being used. An appropriate number of sentries are to patrol the perimeter of the controlled area to prevent unauthorised entry.

11 All controlled areas are to be suitably described in local orders. For site radiography, this can most easily be achieved by stating distances from the sealed source or X-ray machine.

EQUIPMENT REQUIREMENTS

X-Ray Apparatus

Note: The following requirements are not applicable to EOD operators using pulsed x-ray equipment. Specific requirements for EOD operators are given at annex E to this leaflet.

12 Where X-ray machines are used, the following requirements are to be fulfilled:

12.1 The beam filtration on the X-ray tube must be equivalent to at least 2 mm of aluminium;

12.2 The leakage rate from the X-ray tube housing is to not exceed 2.5 mSv h^{-1} at 1 m from the focal spot at the maximum rated voltage and current, and for pulsed X-ray tubes at the maximum pulse rate;

12.3 The lengths of cables from the X-ray machines are to be long enough to enable the control panel, whenever practicable, to be outside the controlled area;

12.4 For X-ray units operating up to 300 kV, a cable of not less than 20 m in length are to be used. Longer cables are required for X-ray units operating at greater than 300 kV. Control cables to warning signal devices are to be equal or greater in length than the tube head to control panel cables;

12.5 The X-ray set is to be provided with a means of collimation to restrict the radiation beam to the minimum size necessary for the work;

12.6 The equipment is to be electrically safe;

12.7 The equipment is provided with a means of preventing unauthorised use (e.g. a key operated switch).

Sealed Sources

13 Sealed sources used in site radiography are to be provided with a suitable means of collimation to restrict the extent of the radiation beam to a minimum necessary to undertake the work and operated via a keyed switch to prevent unauthorised use.

WARNING SIGNALS

14 Adequate warning of the impending or actual presence of radiation is to be given to all persons within or approaching the marked off area during site radiography by appropriate visual or audible signals, or both. The two signals are as follows:

14.1 When a source is about to be exposed or when an X-ray machine is about to be energized (pre-exposure warning alarm);,

14.2 While a source is exposed or an X-ray machine is energized (continuous exposure warning alarm).

15 The duration of the pre-exposure warning alarm is to be sufficient for anyone within the controlled area to walk clear.

16 The pre-exposure and the continuous exposure warning signals must be easily distinguishable from each other. Both signals must be clearly explained on well sited notices at the boundary. The notice is to explain the significance of the barrier. Warning signals and notices may be combined in the form of illuminated notices.

17 In the case of sealed sources capable of delivering 600 mSv h^{-1} at a distance of 1 m in air, and all X-ray apparatus, the warning signals are to operate at or near the X-ray tube head, at the control panel and be clearly recognisable at the boundary of the area. The pre-exposure and the continuous exposure signals are to operate automatically and the equipment is to be unable to function unless they are connected. Work is to cease if the warning signals are not operating correctly. Interlock defeat switches are to not be fitted. A device is to be provided to enable the warning signals to be tested while the X-ray head remains de-energized.

18 In the case of other sealed sources, warning lamps are generally used which are switched on manually, and these are to be in good working order. They must be positioned so that they are clearly visible to all persons in the vicinity. The pre-warning alarm is usually an audible alarm, such as a manually operated air horn.

19 All warning signals are to be examined and tested on a regular basis and records are to be kept of the tests undertaken.

PRECAUTIONS WITH HIGH OUTPUT MACHINES

20 Some X-ray machines, particularly those manufactured after 1992, feature an automatic warm-up facility. To ensure compliance with the manufacturer's specification such sets are to be warmed up at least once in every four week period even if they are not in routine use. The leakage dose rates from such equipment during this warm-up period may be up to 2.5 mSv h^{-1} at 1 m, even when fitted with main beam blanking plugs. Local orders and written operating procedures are to address the precautions to be taken during the warm-up period.

OPERATING PROCEDURES

21 Written operating procedures are to be drawn up for all X-ray machines and sealed sources by the parent establishment of the radiographers, in consultation with their RPA. A copy of the operating procedure is to be displayed at the control point during each such exposure. The general points to be considered in a written operating procedure are contained in the following paragraphs.

22 A controlled area is to be set up in accordance with the requirements above. It is important that control cables are laid out so as to maximise the distance of the operator from the X-ray tube head. The control point is to be, whenever possible, outside the controlled area, and where this is so it is to be continuously manned throughout the whole period of the exposure. At least two classified persons are to be employed on each radiographic exposure, one of these must be an experienced radiographer and the other is to have sufficient knowledge of the actions to be taken in the event of an emergency.

23 Where the control point is inside the controlled area, operators are to only enter the controlled area to start the exposure, terminate the exposure or in the event of an emergency. In exceptional circumstances where it is necessary for an operator to man the control point inside the controlled area the dose rate at the control point is to not exceed $25 \mu\text{Sv h}^{-1}$.

24 After setting up the controlled area and before exposure, all persons within the area not involved with the radiography are to leave. A thorough search of the area is to be conducted with special attention being paid to places where personnel may remain unobserved, such as remote compartments and the interior of empty tanks.

25 The radiography set-up is to be completed before any sealed source is exposed or X-ray machine is energized. No changes to the exposure arrangements are to be made during an exposure.

26 Sufficient sentries are to be posted around the perimeter of the area to prevent entry to the controlled area during radiography. Care is to be taken to ensure that there are no areas where personnel can enter unobserved. Where it is not practicable to provide line of sight communication between sentries it may be necessary to provide a voice communication system.

27 To ensure that radiation exposure to personnel is kept as low as reasonably practicable the following conditions are to be satisfied:

27.1 The useful beam is to be directed away from the control point and all occupied areas, unless these areas are adequately protected by distance or shielding;

27.2 The beam size is to be kept to the minimum compatible with obtaining a satisfactory radiograph;

27.3 Only authorised persons are to enter the controlled area

28 On completion of the radiation exposure, the X-ray set is to be switched off, or the radiation source retracted into its container. Where a sealed source is used, the radiographer must approach the source container using an appropriate dose rate meter and confirm that the source is fully home in its container.

29 The movement or manipulation of sealed sources is to be undertaken by remote control. Care is to be taken to prevent any part of the body coming close to the exposed source. Radiographic sources must never be handled with bare or gloved hands. All unnecessary movement of sources must be avoided. Sources are to only be moved about a unit when they are locked in their containers and their keys have been removed.

MONITORING SURVEYS

30 A radiation survey record is to be maintained, containing details of radiation dose rates at the barrier and within controlled areas where persons are exposed to levels of radiation in excess of $7.5 \mu\text{Sv h}^{-1}$. Radiation survey records are to be maintained for at least 2 years from the date of the survey, unless there is an incident in which case the records are to be kept indefinitely.

RADIOGRAPHY SAFETY AUDITS

31 Regular and random checks on site radiography are to be made to ensure the procedures are being carried out to the required safety standards. Such checks are to be carried out by the site RSO or other suitably qualified and experienced person.

EMERGENCY PROCEDURES

32 Contingency plans are to be drawn up (in accordance with Leaflet 2 and Leaflet 40) by the establishment in consultation with the RPA to cope with any foreseeable emergency. A copy of these plans and a set of emergency equipment described in these plans are to be carried to each radiographic site. Radiographic sources and containers are designed to withstand fire; if a fire occurs the sources are to only be removed from the area if this can be done without risk to life. If this cannot be done they are to be abandoned and the fire fighting services informed of their presence as soon as possible.

33 Special equipment is to be available to deal with emergencies such as detached sources, jammed sources and damaged containers. The equipment is listed as follows:

- 33.1 Audible alarm monitor;
- 33.2 Personal integrating dosimeter;
- 33.3 Tongs or CeeVee reachers (1 metre and 2 metre);
- 33.4 Pliers, screwdriver, long-handled wire cutters;
- 33.5 Adjustable spanner or wrench, rope, hand lamp;
- 33.6 Tripod (2 metres high - to hoist end of the projection tube to help gravity return of a detached source);
- 33.7 Radiation barrier (quick erect type);
- 33.8 Two bags of lead shot (2 kg each), for Iridium-192 source;
- 33.9 Ten bags of lead or lead shielded semi-cylindrical tunnel for Cobalt-60 sources;
- 33.10 Emergency storage container;
- 33.11 Pouring funnel to suit emergency storage container, for speedy placing of the source.

34 Each person involved in site radiography is to be familiar with the content of these contingency plans. Contingency plans are to be regularly practised using dummy sources etc. to ensure that all personnel are aware of the actions they are to undertake. Records (including the names of personnel involved) should be kept of practices of contingency plans.

35 Contingency plans for site radiography are to be submitted to the Health and Safety Executive if requested by them.

LEAFLET 28 ANNEX D**RADIATION SAFETY ARRANGEMENTS FOR UNDERWATER RADIOGRAPHY****CONTENTS****Para**

- 1 Introduction
- 2 Co-operation between units
- 3 Appointments
- 4 Storage of radioactive sources
- 5 Controlled areas
- 9 Equipment requirements
- 11 Local orders
- 12 Warning signals
- 17 Monitoring surveys
- 18 Audits
- 19 Emergency procedures

INTRODUCTION

1 The main body of this leaflet details the general statutory and MOD mandatory instruction for radiation safety in industrial radiography. Annex B provides guidance on radiation safety for site radiography, which includes a number of provisions common to those required for underwater radiography. This Annex, which must be read in conjunction with the main body of this leaflet and also Annex B (site radiography), provides **additional** guidance specific to the radiation safety arrangements for underwater radiography. Such radiography involves the generation of radiographs using radiation emitted from high-activity sealed sources. High-activity sealed sources used in radiography are capable of delivering overexposure levels of dose at 50 cm in minutes.

CO-OPERATION BETWEEN UNITS

2 The procedures detailed at Annex B to this Leaflet are to be followed.

APPOINTMENTS

3 Underwater radiography requires a number additional factors to be considered regarding the appointment of suitably qualified and experienced staff as follows:

3.1 A Radiation Protection Supervisor (RPS) is to be appointed in writing by the CO for underwater radiography undertaken within a ship or establishment and for the storage of radiographic sources in a source store;

3.2 All RPSs who undertake supervision of underwater radiography are to be trained in accordance with the requirements of this leaflet and Leaflet 15. The training is to specifically include radiation safety aspects of underwater radiography;

3.3 The RPS for underwater radiography is to normally be the diving supervisor (provided they have received the necessary training). Where the diving supervisor and the RPS are not the same person they are to establish close liaison to ensure radiation protection of all personnel, (especially those under pressure or underwater) and each is to be clear of their own individual responsibilities with regard to the radiation protection arrangements;

3.4 As well as the general duties of an RPS, the RPS is to ensure that:

- 3.4.1 All personnel directly involved in, or who may be affected by, the radiography are aware that such work is going to take place;
- 3.4.2 Verbal contact is maintained with all relevant personnel, either under pressure or underwater, while radiography is taking place;
- 3.4.3 All equipment and services are compatible and in working order;
- 3.4.4 No other diving or underwater activity takes place in the controlled area;
- 3.4.5 No other work or conflicting activities takes place in the vicinity which could adversely affect the divers or the radiographic set-up;
- 3.4.6 The exposure container and source are safely returned to the surface.

STORAGE OF RADIOACTIVE SOURCES

- 4 The procedures detailed at Annex B to this Leaflet are to be followed.

CONTROLLED AREAS

- 5 The boundary of the controlled area underwater is to generally be set at 8 m from the source, although this is to be confirmed by dose rate measurements. The figure of 8 m has been chosen because it is a safe practical distance for all radiography sources, and corresponds to current lengths of wind outs used in underwater radiography. In exceptional circumstances, where this distance cannot be achieved, measurements are to be made to ensure that the dose rate at the position to which the divers retire is less than $7.5 \mu\text{Sv h}^{-1}$. This position is to be clearly identified e.g. by a sign or, in poor visibility, by a flashing light.
- 6 Supervision is to ensure that no-one is in a controlled area when the radiographic exposure is taking place. It is to be borne in mind that underwater dose rates increase very rapidly on approaching the source.
- 7 Providing that the above conditions are met, barriers and warning signs need not be erected around the controlled area.
- 8 If radiography is carried out within 8 m of the surface, surface supervision is to ensure that no-one enters the controlled area. Where the dose rate at the surface of the water exceeds $7.5 \mu\text{Sv h}^{-1}$ the guidance for site radiography is to be followed. If this happens offshore that guidance is to be adapted to suit local conditions.

EQUIPMENT REQUIREMENTS

- 9 Only exposure containers which meet the requirements of ISO 3999:2004 or its equivalent, and which are designed to be suitable for use underwater, are to be used. The additional features for use underwater are to include:
 - 9.1 A depth rating for the container which is to state the maximum depth at which the container may be used;
 - 9.2 Seals that either prevent the entry of gas or water into parts that are not designed to withstand them or, if designed to cope with water and gas, allow it to escape during ascent to the surface;
 - 9.3 An integral locking device: the locking device when closed, is to retain the source in the shielded position and, if damaged while the source is exposed, is to not prevent the source from being returned to the shielded position;
 - 9.4 A wind out, exposure or shutter mechanism which can be operated from outside the controlled area;

9.5 For exposure containers with wind-out mechanisms, a method for securely attaching the guide tubes. The tubes are to be fitted before the container is taken into the water;

9.6 An emergency location device e.g. strobe light (see section on warning signals below).

10 Regular attention to and checking of radiography equipment used underwater is of great importance, because such equipment is subjected to environmental conditions that can cause rapid deterioration of its standard of performance. After an item of equipment is used under water it is to be cleaned with fresh water, have its moving parts checked for effective operation and, where necessary, be dried, lubricated and kept in a safe and secure store. Exposure containers are to be checked with a dose rate meter to ensure that wind-out and exposure mechanisms operate correctly before and after cleaning. These checks are to be made by an RPS in an area set aside for this purpose and a record of these checks maintained.

LOCAL ORDERS

11 Local orders are to be provided and include the requirements laid down in Leaflet 16. Specifically the individual radiation protection responsibilities of the RPS and the diving supervisor are to be clearly defined and documented. In addition the local orders are to include the information that will enable the following to be carried out:

- 11.1 Designation and demarcation of controlled areas;
- 11.2 Restriction of access into controlled areas and prevention of accidental exposures, (e.g. intercommunication and supervision);
- 11.3 Prevention of interference with the radiographic set up, (e.g. by remotely operated vehicles or by umbilicals or down lines);
- 11.4 Training and familiarisation with equipment;
- 11.5 Dose assessment of personnel involved, (e.g. for all radiographers, radiographic assistants and divers directly involved in radiography);
- 11.6 Monitoring procedures, (e.g. to ensure after each exposure that the source has returned properly);
- 11.7 Safe operation of source exposure mechanism;
- 11.8 Wind out cables where fitted are to be kept as straight as possible and at least 8 m long;
- 11.9 With remotely operated exposure equipment, only when instructions from the diver indicate that everyone is outside the controlled area;
- 11.10 An appropriate summary of the working instructions, including the written arrangements relating to unclassified persons entering or working in a controlled area;
- 11.11 Prevention of accidental exposure whilst the source is being transferred to and from the surface;
- 11.12 Provision of adequate additional warning signals for work in poor visibility.

WARNING SIGNALS

12 When wet transfer is intended, a short line with a buoy and an emergency location device, e.g. a strobe light, is to be securely attached to it until it is returned to the store. This will aid recovery from the water if the container is dropped. The container is to then be attached to the down line for manual lowering.

13 All warning signals are to be clearly discernable. The underwater detection unit is to include an automatic warning light which operates when the dose rate exceeds $25 \mu\text{Sv h}^{-1}$ close to the container. Such a light is to be clearly visible to all in the vicinity of the controlled area and a repeater warning light and audible alarm are to be fitted near to the surface read out unit. The light is to be visible to any diver approaching the controlled area. It is advantageous to use a closed circuit TV system so that the diving supervisor and the RPS can see the underwater detection unit and check that the warning light operates correctly. Otherwise, the check is to be carried out verbally between the divers and surface personnel.

14 When visibility is poor, additional warning signals will be needed unless all personnel have returned to the surface before the exposure begins.

15 The divers (including standby divers) in the immediate vicinity are to have in their possession personal radiation alarms which give an instant indication of high dose rates. These alarms are to be properly calibrated and set to operate at $25 \mu\text{Sv h}^{-1}$. An alarm is to trigger a flashing light which is to be visible to the diver in all light conditions. If personal alarms operate, those involved are to move to a safe place (i.e., where the alarms cease to operate) and immediately contact the RPS.

16 All warning signals are to be examined and tested on a regular basis and records are to be kept of the tests carried out. The frequency of examination and testing should be at least once per year. Records should be kept for at least 2 years, and form part of the maintenance log for the equipment.

MONITORING SURVEYS

17 The procedures detailed at Annex B to this Leaflet are to be followed.

AUDITS

18 The procedures detailed at Annex B to this Leaflet are to be followed.

EMERGENCY PROCEDURES

19 Contingency plans adopted for underwater radiography are to be written as for site radiography. Any differences between underwater and site radiography will stem from the shielding effect of water, the depth of the water and the allocation of duties, e.g. the diving supervisor's involvement. A copy of these plans and a set of emergency equipment described in them must be carried to each radiographic site.

LEAFLET 28 ANNEX E**RADIATION SAFETY ARRANGEMENTS FOR
INDUSTRIAL FLASH AND PULSED X-RAY EQUIPMENT****CONTENTS****Para**

- 1 Introduction
- 4 Monitoring surveys
Flash X-ray equipment
- 5 Classification of personnel and dosimetry
- 6 Controlled areas
- 10 Warning signs
- 15 Operating procedures
- 16 Pulsed X-ray equipment
- 17 Classification of persons and dosimetry
- 19 Controlled areas
- 20 Operating procedures

INTRODUCTION

1 The main body of this leaflet details the general statutory and MOD mandatory instruction for radiation safety in industrial radiography. This Annex provides guidance specific to the radiation safety arrangements for industrial flash and pulsed X-ray equipment.

2 Flash X-ray equipment is used to provide images of extremely fast events. The duration of the exposure is therefore extremely short but, from the larger scale equipments, the dose at 1m from a single flash exposure could be in excess of lethal dose levels.

3 Pulsed X-ray equipment is normally associated with portable equipment, used for example to investigate potential explosive devices. This equipment involves a number of short pulses of X-rays being passed through the object to be radiographed. The total exposure depends on the number of pulses required and the X-ray energy. Typical dose from a single pulse at a distance of 1m is a few μSv but close in at a few cm rises to mSv levels per pulse.

TRAINING

4 Full training in accordance with Paragraph 13 of Leaflet 28 is not necessary for EOD pulsed x-ray radiography. Suitable training will be provided by a recognised EOD training school, where that training school has consulted the appointed RPA on the content of the training syllabus

MONITORING SURVEYS

5 It is not possible to conduct surveys with standard radiation monitoring equipment as the exposure time is shorter than the response time of the equipment. Specialised equipment can be used to determine doses per flash or pulse – the RPA is to be consulted for advice in this matter.

FLASH X-RAY EQUIPMENT**Classification of personnel and dosimetry**

6 Generally, operators of flash X-ray equipment under site radiography conditions will be designated as classified persons (see Leaflet 4) and will be required to wear dosimeters (see Leaflet 6), issued by an Approved Dosimetry Service (ADS), usually the Dstl ESD Alverstoke ADS.

Controlled areas

7 For flash X-ray carried out in an enclosure, the design of the enclosure and the requirements for a controlled area detailed in Annex A to this leaflet is to be followed.

8 For site flash X-ray, a controlled area is to be established, and where necessary cordoned, around the X-ray equipment, as detailed in Annex B to this leaflet. The extent of controlled areas is to be determined by calculating the appropriate distance from the source of X-rays to the position where the dose rate (averaged over 1 minute) will not exceed $7.5 \mu\text{Sv h}^{-1}$ within an establishment, or $2.5 \mu\text{Sv h}^{-1}$ in public places. In determining this distance, account is to be taken of any shielding. Calculations are to be included with the prior risk assessments for the equipment. When calculating controlled area distances, consideration is to be given to equipment failure scenarios where more than one X-ray pulse may be discharged in any one minute. Such an incident would result in a greater instantaneous dose rate than normal. The RPA must be consulted on the distance to be used for controlled radiation areas for flash X-radiography.

9 All controlled and supervised areas are to be suitably described in local orders. This can most easily be achieved by stating distances from the X-ray equipment to the $7.5 \mu\text{Sv h}^{-1}$ or $2.5 \mu\text{Sv h}^{-1}$ time averaged dose rate contour, as appropriate.

10 Where it is reasonably practicable, the controlled area boundary is to be set at a distance greater than that which equates to $7.5 \mu\text{Sv h}^{-1}$.

Warning signs

11 Warning signs are to be displayed at appropriate points around the perimeter of the controlled areas, such that a person approaching the controlled area from any direction would be made aware of the hazard.

12 A pre-exposure alarm is to signal when the X-ray equipment is about to be energized prior to exposure. The pre-exposure alarm is to be audible up to the moment of exposure and then terminate automatically when the X-ray equipment is discharged. The duration of the pre-exposure warning alarm is to be sufficient for anyone within the controlled area to walk clear. An appropriate number of sentries are to patrol the perimeter of the controlled area to prevent unauthorised entry.

13 It is impracticable to provide a distinct exposure signal, due to the extremely short exposure time (in the order of micro-seconds).

14 The pre-exposure signal must be clearly explained on well sited notices at the boundary. The notices are to explain the significance of the barrier. Warning signals and notices may be combined in the form of illuminated notices.

15 All warning signals are to be examined and tested on a regular basis and records are to be kept of the tests undertaken.

Operating procedures

16 Flash X-ray equipment is to be operated in accordance with local orders and the manufacturer's operating instructions.

PULSED X-RAY EQUIPMENT

17 Pulsed X-ray equipment includes equipment such as the Golden and Inspector series of X-ray sets, used for radiography of potentially explosive devices.

Classification of Persons and Dosimetry

18 It is not normally necessary for operators to become classified persons.

19 Radiation dosimetry, issued by the Dstl ESD Alverstone Approved Dosimetry Service (ADS), is usually required, as advised by the RPA.

20 A controlled area is to be established and where necessary cordoned, around the X-ray equipment. The extent of controlled areas are to be determined by calculating the appropriate distance from the source to the position where the time averaged dose rate will not exceed $7.5 \mu\text{Sv h}^{-1}$ within an establishment, or $2.5 \mu\text{Sv h}^{-1}$ in public places. In practice, it is explosives safety considerations which are most limiting, and the controlled radiation area will be contained within the explosive safety distance. Where consistent with explosives safety considerations, an appropriate number of sentries are to patrol the perimeter of the controlled area to prevent unauthorised entry.

Operating procedures

21 Pulsed X-ray equipment is to be operated in accordance with local orders and the manufacturer's operating instructions. The controlled radiation area (as specified above) is to be cleared of personnel until the operation is complete. When using pulsed X-ray sets, where practicable, the X-ray set is to be directed towards solid walls.

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