28 Industrial Radiography

Scope

1. In accordance with the Ionising Radiations Regulations 2017 specified practices require a Consent to be applied for. The applicable specified practices in MOD include:

a. the operation of an accelerator.

b. industrial radiography.

c. industrial irradiation.

d. any practice involving high activity sealed source.

e. practices discharging significant amounts of radioactive material with airborne of liquid effluent into the environment.

2. In accordance with the Ionising Radiations Regulations 2017, industrial radiography is the use of ionising radiation for non-destructive testing purposes where an image of the item under test is formed (but excluding any such testing which is carried out in a cabinet which a person cannot enter). Industrial radiography applications in MOD include:

a. radiography in enclosures using both high activity sealed radioactive sources (HASS) and X-ray generators (flash, continuous and pulsed);

b. site radiography using high activity sealed sources or X-ray generators (flash, continuous and pulsed); and

c. underwater radiography using high activity sealed sources (HASS).

3. 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 equipment, the dose at 1m from a single flash exposure could be very high.

4. Pulsed X-ray equipment involves a number of short pulses of X-rays being passed through the object to be investigated. 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 closer in can rise to mSv per pulse.

5. This chapter 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 of this Chapter. The Radiation Protection Adviser (RPA) must always be consulted prior to any new activity or change in activity associated with industrial radiography.

6. The scope of this chapter does not extend to the use of accelerators, however many of the principles in this chapter apply. For specific advice regarding accelerators contact DRPS.

Statutory Requirements

7. 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:

a. Ionising Radiations Regulations 2017 (IRR17) (apply directly);

b. Environmental Permitting (England and Wales) Regulations 2016 (EPR16) (as amended) (parallel arrangements);

c. Environmental Authorisations (Scotland) Regulations 2018 (EASR18) (parallel arrangements)

d. Radioactive Substances Act 1993 (Northern Ireland) (as amended) (RSA93) and associated Exemption Orders (parallel arrangements);

e. High activity Sealed Radioactive Sources and Orphan Sources Regulations 2005 (Northern Ireland) (parallel arrangements);

f. Carriage of Dangerous Goods and Transportable Pressure Equipment Regulations 2009 (as amended) (apply directly) (CDGT09); and

g. Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (apply directly) (RIDDOR13).

Duties and Appointments

8. Duties as detailed in Chapter 39 apply. In addition, the following duties also apply.

Commanding Officer and Head of Establishment (CO / HoE)

9. The CO / HoE should ensure that 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 industrial radiography commencing which will involve a change in process to that which has already required consultation with the RPA.

Radiation Safety Officer (RSO)

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

a. the employer undertaking radiography has a consent issued by the HSE for carrying out industrial radiography, this will include ensuring there is a safety assessment as required by the HSE;

b. for units that undertake site radiography for other clients (not being the same employer) that the 7-day notification condition of the HSE consent is being observed and, where applicable, HSE waivers have been obtained; 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 commences;

c. local rules including the specific requirements for industrial radiography are in place;

d. staff are suitably qualified and experienced prior to undertaking industrial radiography and that this process is documented;

e. staff competency is closely monitored, including the need for continuation training and recertification; and

f. 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)

11. A suitable RPA must be appointed in writing and consulted prior to the acquisition of industrial radiography equipment, prior to initially commencing industrial radiography and prior to commencing industrial radiography where there is a substantial change in the practise where the RPA has been previously consulted. For all units and establishments, other than those with a resident RPA, the RPA will normally be the DRPS RPA Body.

Radiation Protection Supervisor (RPS)

12. A suitable Radiation Protection Supervisor (RPS) is to be appointed in writing for all radiography work. 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 IRR17) and the requirements of this Chapter.

Employees

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

a. their dose assessment;

b. their medical surveillance;

c. reporting of any loss or release of radioactive material (report to supervisor); and

d. 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

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

Radiation Source	Typical Maximum Activity (TBq)	Energy (keV)	Half Life	Typical maximum dose or dose rate at 1m
X-ray generator (continuous)	N/A	Up to 300	N/A	>10 Sv/hr
X-ray generator (pulsed)	N/A	Up to 300	N/A	10 mSv per 200 pulses
X-ray generator (flash)	N/A	Up to 1000s	N/A	>10 Sv per flash
Betatron	N/A	Up to 8000	N/A	>10 Sv/hr
Cobalt-60 (Co-60)	4	1170; 1330	5 years	Approx. 1.2 Sv/hr
Iridium-192 (Ir-192)	7	210-610	74 days	Approx. 800 mSv/hr
Caesium-137 (Cs-137)	0.5	660	30 years	Approx. 40 mSv/hr

Table 1: Data for Typical Gamma and X-Ray Sources Used in Industrial Radiography Within MOD

Hazards

15. 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 cause significant tissue damage.

16. Continuous 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. An exposure of a few seconds in close proximity to the X-ray port could be sufficient to cause significant tissue damage.

17. 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.

18. Flash X-ray equipment may operate at very high energy and high-power giving rise to potentially lethal in beam dose levels.

Safety Assessment

19. A safety assessment of the activities and the facility must be undertaken in order to:

a. Identify ways in which potential exposures or accidental and unintended medical exposures could occur; estimate, to the extent practicable, the probabilities and magnitude of potential exposures;

b. estimate, to the extent practicable, the probabilities and magnitude of potential exposures;

c. assess the quality and extent of protection and safety provisions, including engineering features, as well as administrative procedures; and

d. define the operational limits and conditions of operation.

20. Safety assessment templates are available from the HSE website for the various practices requiring consent and the appropriate completed template will need to be submitted to the HSE alongside the local rules and contingency plans before a consent will be approved.

21. Although the RPS and RPA can help with the safety assessment, it will require provision of evidence to show that radiation protection is managed at a senior level. It will need to give details of how RPSs will be given sufficient time and resources to supervise the work so that it is done in accordance with local rules.

Risk Assessments

22. A radiation risk assessment is required before the commencement of any industrial radiography. The risk assessment must consider the specific type of work and enclosure (or otherwise) used. Generic information provided by manufacturers, Project Teams (PT) and this publication may be useful as input to these assessments. It is a statutory requirement that the RPA is consulted regarding a number of aspects. Chapter 2 gives further general instruction and guidance on the components of a radiation risk assessment.

23. 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

24. 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).

25. The RPS is to be familiar with the following publications, in addition to IRR17 and the associated Approved Code of Practice:

a. Radiation Protection Supervisors: Ionising Radiation Protection Series No 6.

b. Personnel Certification in Non-Destructive Testing (NDT) – General Information, e.g. The British Institute of Non-Destructive Testing.

c. HSE Information Sheet – Industrial Radiography – Managing Radiation Risks.

26. 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.

Classified Persons and Dosimetry

27. Unless agreed with the RPA, MOD personnel carrying out industrial radiography are to be designated as classified persons (see Chapter 4) and are to be issued with dosimetry

supplied by an Approved Dosimetry Service (ADS), as advised by the RPA and in accordance with the local rules for the controlled area.

Emergency Procedures

28. Contingency plans are to be drawn up (in accordance with Chapter 2 and Chapter 40) by the establishment in consultation with the RPA to cope with any foreseeable emergency identified in the radiation risk assessment. Contingency plans are to be referenced in local rules and rehearsed at appropriate intervals to ensure their effectiveness and that all personnel are aware of the actions to take. Specific additional requirements for the different types of industrial radiography are provided in the relevant sections below.

29. In the event of a contingency plan being implemented, the RSO / RPS is to investigate and record analysis of events that triggered use of the contingency plan.

Contractors

30. Where contractors are employed to undertake radiography at a unit or establishment, they are to work in accordance with the requirements of the IRR17 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 Chapter, to the satisfaction of the CO through the RSO and / or RPS. Details of general contractor control arrangements are given in JSP 375.

Requirements for Radioactive Sealed Sources and their Containers used for Site and Enclosure Radiography

31. 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. 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 the Dangerous Goods Manual. All exposure containers are to be permanently and indelibly marked (possibly by fitting with a metal plate) with the following information:

a. the radiation trefoil;

b. the word RADIOACTIVE in letters not less than 10 mm high;

c. the maximum rating of the container, for example an Iridium-192 source with a maximum container rating of X Bq would be shown as: Rating X Bq Ir-192;

d. the manufacturer, type and serial number; and

e. the mass of the exposure container if it is Class P, M or F as described in ISO3999:2004.

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

a. chemical symbol and mass number of radionuclides, for example, Ir-192;

b. activity and date activity were measured; and

c. identification number of sealed sources.

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

34. 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.

35. Additional requirements for HASS 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. Further regulatory requirements for the keeping and use of HASS are addressed in Chapter 3.

36. 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 μSv/hr. 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.

37. 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 HASS, the conditions on the approval certificate must be applied.

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

Loading and Unloading of Radioactive sources

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

40. 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, including a risk assessment, contingency plan and local rules, 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.

41. 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

42. 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 NaCTSO. 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.

Guidance on Radiation Safety Arrangements for Industrial Radiography in Enclosures

43. Enclosure radiography involves the generation of intense beams of radiation emitted from high-activity sealed sources or from X-ray generators (continuous, pulsed and flash)

Designation of Radiography Enclosures

44. 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.

45. Suitable controlled radiation areas signs (see Chapter 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.

46. 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.

47. 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.

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

Access to Radiography Enclosures

49. Entry to the radiography enclosure is prohibited during radiation exposure other than in special circumstances under a permit-to-work (see Chapter 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

50. Enclosures for industrial radiography using radioactive sealed sources or X-rays must provide sufficient shielding to reduce the radiation dose rate to 7.5 µSv/hr 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 µSv/hr.

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

52. Where an X-ray set is used, interlocks are to be provided and maintained to ensure that should any door to the enclosure be opened while the X-ray equipment within it is

energised, the X-ray tube will be automatically de-energised and cannot be operated so long as that door remains open.

53. 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.

54. 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 set or sealed source can be exposed.

55. 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.

56. 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.

57. 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.

58. 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.

59. 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.

60. 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

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

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

b. while a source is exposed, or an X-ray machine is energised (continuous exposure warning alarm).

62. The duration of the pre-exposure warning alarm is to be sufficient for anyone accidentally shut inside the enclosure to take appropriate action.

63. 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.

64. For flash X-ray it is impracticable to provide a distinct exposure signal, due to the extremely short exposure time (in the order of micro-seconds).

65. In the case of X-ray machines, and sealed sources capable of producing >10 mSv min-1 at a distance of 1m, the warning signals and illuminated signs are to be arranged to operate automatically.

66. Warning signals are to be installed inside the enclosure and outside each entrance to the enclosure.

67. 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.

68. 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.

69. 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.

70. Explanatory notices are to be provided to inform employees and other persons as to the purpose of the warning signal.

Operating Procedures

71. 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 Chapter 16). Non-classified persons are only to enter a controlled area under written arrangements (see Chapter 5).

72. 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.

73. 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.

74. Where there are limitations on the location of the equipment inside the enclosure, the radiography source or the X-ray machine is only to be operated in the demarcated area.

75. 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.

76. 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.

77. 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.

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

Radiation Safety Arrangements for Site Radiography

79. Site radiography involves the generation of radiographs using radiation emitted from HASS or from X-ray generators (continuous, pulsed and flash)

Co-operation between Units

80. All those undertaking site radiography must comply with the conditions within the consent issued by the HSE (see Chapter 3). HSE consents for site radiography include a condition that site radiography must not be performed without 7 days written notice form the client (person requesting the radiography) to the radiography employer (consent holder) on each and every occasion the work is carried out. This allows time for the work to be properly planned and for there to be adequate liaison between the site radiography consent holder and the client to take place.

81. Prior to site radiography taking place the RSO, or other person(s) nominated by the RSO, such as the 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 (or other such responsible person) of the Non- Destructive Testing (NDT) team:

a. prior notification and permission for the NDT source or X-ray machine to be brought on site;

b. name of RPAs and RPSs and how they can be contacted on or off site;

c. places where work will be carried out including dates and description of work procedures and work instructions;

d. details of radioactive sources or X-ray machines to be used;

e. for sources only, their stowage requirements including both safety and security aspects;

f. description of monitoring procedure;

g. risk assessments and contingency plans;

h. details of methods of transportation of sources; and

i. radiography local orders and procedures for the radiographers.

82. Where the unit requesting site radiography and the NDT team have the same employer there is no requirement for the consent holder to receive 7 days written notification of the work but there must be sufficient time to ensure that the work is properly planned, and risk assessed. 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.

83. In circumstances where 7 days written notification is required the consent holder may apply to the HSE for a waiver from the requirement for 7 days written notification prior to each job for the following circumstances:

a. embedded work;

(1) this is when the site radiography company has a permanent or semi-permanent presence on their client's site;

(2) the radioactive sources and / or radiation generators are stored at their client's site when not in use, or transported there on a daily basis;

(3) site radiography is performed at least several times per week; and

(4) the waiver will be granted for a period of one year.

b. time bounded periodic work; and

(1) site radiography carried out periodically at the same client's site over a given time period;

(2) cannot be specific of the date or time the site radiography will take place;

(3) site radiography company has been given notice of the work;

(4) radiography is carried out at least 10 times in a 3-month period; and

(5) the given time period cannot exceed 3 months.

c. emergency situations.

84. A site radiography company may be called upon to carry out work without 7 days written notice being given by their client because:

a. significant immediate safety risk; and / or

b. significant cost implications of delaying work; or

c. it is not reasonably practicable to delay such work.

85. It must be a genuine unforeseen event. Lack of notice due to poor planning or finishing a job quicker is not an emergency.

86. The client will have to demonstrate the work has been adequately planned and can be done safely.

87. Applications for waivers are submitted by email to siteradwaivers@hse.gov.uk.

Appointments

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

a. 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;

b. 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 has a duty to ensure that radiation doses are kept as low as reasonably practicable for personnel involved in the radiography and for all other persons who may receive radiation doses from the radiography;

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

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

(1) all personnel directly involved in, or who may be affected by, the radiography is aware that such work is going to take place;

(2) verbal contact is maintained with all relevant personnel while radiography is taking place;

(3) all equipment and services are compatible and in working order; and

(4) no other work or conflicting activities take place in the vicinity which could adversely affect the safety of any person or the radiographic set-up.

Storage of Radiography Sources

89. 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 Chapter 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. The site RSO is to be notified of the location of the source. 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).

90. For short term exercises, where sources are used away from their base locations, and suitable ‘Mobile notification’ is in place from the relevant environmental regulator, 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. The conditions on the approval must be applied.

Controlled Areas

91. 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:

a. within an establishment, all areas outside the controlled area are to be at dose rates (averaged over one minute) of less than 7.5 µSv/hr. Barriers and signs are to be set up where dose rates exceed 2.5 µSv/hr;

b. 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 µSv/hr dose rate contour within an establishment. 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 µSv/hr or 2.5 µSv/hr, as appropriate;

c. 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); and

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

92. Except where it is unavoidable for the purposes of initiating or terminating an exposure, where dose rates up to 2mSv/hr would be permissible, no one is work inside the controlled or supervised areas until the exposures are complete.

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

94. Suitable warning signs (see Chapter 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.

95. 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

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

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

b. the leakage rate from the X-ray tube housing is to not exceed 2.5 mSv/hr at 1 m from the focal spot at the maximum rated voltage and current;

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

d. for X-ray units operating up to 300 kV, cables 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;

e. 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;

f. the equipment is to be electrically safe; and

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

Sealed Sources

97. 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

98. 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:

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

b. while a source is exposed, or an X-ray machine is energized (continuous exposure warning alarm).

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

100. The pre-exposure and the continuous exposure in progress 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.

101. In the case of 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 not to be fitted. A device is to be provided to enable the warning signals to be tested while the X-ray head remains de-energised.

102. For flash X-ray it is impracticable to provide a distinct exposure signal, due to the extremely short exposure time (in the order of micro-seconds).

103. In the case of 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.

104. 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

105. Some X-ray machines feature an automatic warm-up facility and are to be warmed up at a frequency specified by the manufacturer 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/hr 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

106. At least one designated RPS needs to be present on the site or establishment for the duration of any radiographic procedure. The RPS must be easily contactable by the radiographers undertaking the task.

107. 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.

108. 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 both are to have sufficient knowledge of the actions to be taken in the event of an emergency.

109. 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 µSv/hr.

110. 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.

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

112. 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.

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

a. 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;

b. the beam size and exposure duration are to be kept to the minimum compatible with obtaining a satisfactory radiograph; and

c. only authorised persons (these must be at least classified persons or people working in accordance with written procedures) may enter the controlled area.

114. 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. Where an X-ray set is in use the radiographer may only enter the controlled area and using a suitable radiation monitoring instrument confirm that the exposure is terminated.

115. The movement or manipulation of sealed sources is always 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 the shielded positions in their containers and the keys have been removed.

Monitoring Surveys

116. 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 µSv/hr. 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.

117. For flash and pulsed X-ray radiography it is not possible to conduct surveys with standard radiation monitoring equipment as the exposure time during flash or pulsed X-ray radiography is shorter than the response time of the equipment. Specialised equipment or certain types of dosimetry may be used to estimate doses per flash or pulse – the RPA is to be consulted for advice in this matter.

Radiography Safety Audits

118. 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

119. Contingency plans are to be drawn up (in accordance with Chapter 2 and Chapter 40) by the establishment in consultation with the RPA to cope with any foreseeable emergency identified in the radiation risk assessment. 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 severe fires; if a fire occurs the sources are only to 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.

120. 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:

a. audible alarm monitor.

b. personal integrating dosemeter.

c. tongs or CeeVee reachers (1 metre and 2 metre).

d. pliers, screwdriver, long-handled wire and bolt cutters.

e. adjustable spanner or wrench, rope, hand lamp.

f. tripod (2 metres high - to hoist end of the projection tube to help gravity return of a detached source).

g. radiation barrier (quick erect type).

h. two bags of lead shot (2 kg each), for Iridium-192 source.

i. ten bags of lead or lead shielded semi-cylindrical tunnel for Cobalt-60 sources.

j. emergency storage container.

k. pouring funnel to suit emergency storage container, for speedy placing of the source.

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

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

Radiation Safety Arrangements for Underwater Radiography

123. Underwater radiography involves the generation of radiographs using radiation emitted from high-activity sealed sources. HASS used in radiography are capable of delivering overexposure levels of dose at 50 cm in minutes.

Co-operation between Units

124. The procedures detailed in site radiography are to be followed.

Appointments

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

a. 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;

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

c. 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 duties with regard to the radiation protection arrangements; and

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

(1) all personnel directly involved in, or who may be affected by, the radiography is aware that such work is going to take place;

(2) verbal contact is maintained with all relevant personnel, either under pressure or underwater, while radiography is taking place;

(3) all equipment and services are compatible and in working order;

(4) no other diving or underwater activity takes place in the controlled area;

(5) no other work or conflicting activities takes place in the vicinity which could adversely affect the divers or the radiographic set-up; and

(6) the exposure container and source are safely returned to the surface.

Storage of Radioactive Sources

126. The procedures detailed in site radiography are to be followed.

Controlled Areas

127. The boundary of the controlled area underwater is to be established prior to the task based upon estimates made in the task risk assessment. Generally, the boundary should be set at be set at 8m (in three dimensions) 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 μSv/hr. This position is to be clearly identified e.g. by a sign or, in poor visibility, by a flashing light. If there is any doubt in the extent of the controlled area the RPA must be consulted.

128. 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.

129. Providing that the above conditions are met, barriers and warning signs need not be erected around the controlled area.

130. 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 μSv/hr 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

131. 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:

a. a depth rating for the container which is to state the maximum depth at which the container may be used;

b. 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;

c. 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;

d. a wind out, exposure or shutter mechanism which can be operated from outside the controlled area;

e. 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; and

f. an emergency location device, e.g. strobe light (see section on warning signals below).

132. 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 Rules

133. Local rules are to be provided and include the requirements laid down in Chapter 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 rules are to include the information that will enable the following to be carried out:

a. designation and demarcation of controlled areas;

b. restriction of access into controlled areas and prevention of accidental exposures, (e.g. intercommunication and supervision);

c. prevention of interference with the radiographic set up, (e.g. by remotely operated vehicles or by umbilical's or down lines);

d. training and familiarisation with equipment;

e. dose assessment of personnel involved, (e.g. for all radiographers, radiographic assistants and divers directly involved in radiography);

f. monitoring procedures, (e.g. to ensure after each exposure that the source has returned properly to its shielded position);

g. safe operation of source exposure mechanism;

h. wind out cables where fitted are to be kept as straight as possible and are at least 8m in length;

i. with remotely operated exposure equipment, only make exposures when instructions from the diving supervisor indicate that everyone is outside the controlled area;

j. an appropriate summary of the working instructions, including the written arrangements relating to non-classified persons entering or working in a controlled area is available and has been read and understood by them;

k. prevention of accidental exposure whilst the source is being transferred to and from the surface; and

l. provision of adequate additional warning signals for work in poor visibility.

Warning Signals

134. 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.

135. All warning signals are to be clearly discernible. The underwater detection unit is to include an automatic warning light which operates when the dose rate exceeds 7.5 μSv/hr 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.

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

137. 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 µSv/hr. 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.

138. 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

139. The procedures detailed in site radiography are to be followed.

Audits

140. The procedures detailed in site radiography are to be followed.

Emergency Procedures

141. 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.