29 Items and Components Containing Thorium

Scope

1. Thorium is a naturally occurring radioactive material and is widely used within MOD in magnesium alloy aircraft components, optical lenses and some laboratory compounds. Obsolete thoriated items include gas mantles, thoriated welding rods and night flares from the Milan weapon system. Thorium is not used for its radioactive properties but rather because of its physical properties e.g. as a hardening agent in lightweight magnesium alloys; for the optical qualities it imbues when incorporated in lenses or lens coatings; and for its incandescence properties.

2. This Chapter describes the radiological requirements for keeping, using and disposing of such items and components. General information and instruction on the hazards associated with thorium, personnel duties and responsibilities; as well as statutory and MOD mandatory requirements are provided in the body of the Chapter. Further information and guidance on each major type of item or component, and the risks posed, is provided at the Annexes. The Radiation Protection Adviser (RPA) is to be consulted for detailed advice on specific applications involving thorium.

Statutory Requirements

3. 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. The Environmental Permitting (England & Wales) Regulations 2016 (EPR16) (as amended) (parallel arrangements);

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

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

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

Duties

4. Duties as detailed in Chapter 39 apply.

Nature of Thorium

5. The major source of thorium in nature is monazite sand containing up to 12% by weight of thorium oxide. Thorium occurs in nature as thorium-232 (Th-232) which has an extremely long half-life (many millions of years). Th-232 has 10 radioactive daughters of much shorter half-lives which exist in equilibrium with the parent nuclide and contribute to the overall radioactivity of natural thorium. The activity of natural thorium is 4.1 kBq g^{-1} of Th-232 together with similar activity levels of each daughter. Th-232, together with its daughters, emits alpha, beta and gamma radiation.

6. Thorium and thorium / magnesium alloys are prone to corrosion if allowed to weather, resulting in a loose powdery oxide which can pose a contamination hazard.

7. Specialised chemical processing, such as that used to prepare laboratory compounds, can separate Th-232 from other non-thorium daughter nuclides resulting in a rather different nuclide and radiation profile. For bulk solids containing processed thorium, the full equilibrium is slowly restored over about 30 years. Finely divided thorium (e.g. a powder) can allow the release of the gaseous daughter product radon-220 (also called thoron) which can affect the equilibrium and change the nuclide and radiation profile.

8. Detailed advice on the radioactive nature and properties of thorium can be sought from the RPA.

Hazards

Alpha

9. High energy alpha radiation is emitted by Th-232 and 6 of its 10 radioactive daughter products. Alpha radiation is absorbed effectively by a thin layer of all materials, including the dead surface layer of skin, or a few cm of air and hence is not normally considered an external radiation hazard. However, in the case of some optical lenses containing or coated with thorium material, a significant alpha dose could be received by the eye (surface of the cornea) if the eye is placed close to the thoriated lens.

10. Alpha radiation poses a potential internal hazard e.g. inhalation of airborne thorium material (machining, gas mantles, welding), ingress through or via the skin of loose thorium arisings and ingestion of contamination.

11. Finely divided thorium (powders etc) can allow some Radon-220 (daughter product) gas to reach atmosphere – this leads to an additional internal radiation hazard.

Beta

12. Beta radiation is emitted by 5 of the 10 radioactive daughters of Th-232. Beta radiation penetrates through thin layers of material and travels up to a few metres in air. Beta will contribute to the external radiation dose received by the eye from some thoriated lenses (see above). Beta will also contribute to the external radiation dose where personnel are in close proximity to thorium items and components containing thorium alloys. In the latter case, only beta radiation from surface layers (a few mm in depth) contributes to dose due to self-absorption of beta emitted within the bulk material.

13. Beta radiation poses a potential hazard from inhalation, ingress through or via the skin and ingestion as indicated for alpha above.

14. Low levels of Bremsstrahlung radiation (X-rays) are emitted from items and components containing thorium.

Gamma

15. Gamma radiation is emitted by thorium and its daughter products. This gives rise to an external radiation hazard. Dose rates are dependent on concentration and quantity of thorium and also the design and structure of the equipment. Dose rates can be sufficient to require areas to be designated as controlled or supervised (see annexes to this Chapter).

Risk Assessments for Items and Components Containing Thorium

16. A risk assessment is to be carried out by units and establishments, in consultation with the RPA, on each new or existing activity using equipment containing thorium. The assessment must take account of local factors and recommended control measures. Chapter 2 describes the process to be followed in carrying out a radiological risk assessment. The general legal and MOD mandatory requirements for work with thorium are given in Table 2. Specific hazard and risk information for the following applications is given at Annexes A, B and C respectively:

a. thoriated magnesium alloy components (e.g. aircraft engine components);

b. thoriated lenses; and

c. thoriated welding electrodes.

Risk assessments for work involving laboratory compounds of thorium

17. Work with thoriated laboratory compounds invariably involves work with open sources of radioactivity. The hazards and risks of this work and the necessary control measures vary widely depending on the application. For this reason, the RPA must always be consulted prior to the work commencing in regard to the radiation risk assessment, the need for area designation, contingency plans and the control measures necessary for safe management of the work and use and disposal of the radioactive materials.

Obsolete items containing thorium – gas mantles and Milan night flares

18. Some old types of incandescent gas mantles used in HPP (Tilley) lamps contain thorium. These gas mantles are obsolete and should be disposed of through an authorised disposal route. The replacement gas mantles that do not contain thorium can be identified by a band of green thread running through the mantle and from the packaging, which bears a radiation trefoil symbol with “X”, marked through it.

19. Milan night flares were attached to the back of the missile and may be found on firing ranges where the missiles landed.

20. Advice on the hazards and disposal of these items can be obtained from the RPA / Radioactive Waste Adviser (RWA).

Thoriated Magnesium Alloy Components – Hazard and Risk Information

Thoriated Magnesium Alloy Components	
Description	Thorium can be incorporated into engine components to instil creep resistance at elevated temperatures. Typically, up to 4% by weight (w/w) of thorium is present.
Radionuclide	Thorium-232 (Th-232) and 10 radioactive daughter products including Ra-228, Th-228, Ra-224 and Rn-220.
Ionising radiation	Alpha, beta and gamma radiation from mix of parent and daughter nuclides.
Half life	1.4 x 10^{10} years (Th-232)
Activity	4% w/w alloys contain approximately 160 Bq g^{-1} of Th-232 and up to 1500 Bq g^{-1} of daughter products.
External radiation hazard	Gamma radiation is emitted from thoriated engines/alloy components, beta radiation from surface layers up to a few mm deep and alpha radiation from the immediate surface layer. 4% w/w alloys give whole body contact dose rates of up to 20 µSv h^{-1} and skin dose rates of up to 160 µSv h^{-1} skin. Dose rates fall off rapidly with distance such that significant exposure is only likely for those who work in close proximity for extended periods.
Internal radiation hazard	Drilling or machining can create radioactive dust. Corrosion generates white powdery thorium oxide which can be released as contamination during handling, maintenance and refurbishment. The radioactive dust emits alpha, beta and gamma radiation which can be an internal hazard via inhalation, ingestion, skin contamination and ingress through cuts or abrasion in the skin. Working (unprotected) on a 4% alloy and generating dust levels of a few mg/m^3 could lead to an inhalation dose rate of up to 40 µSv h^{-1}.
Local orders	Details of the control measures taken from this Chapter are to be included in the local orders for radiation safety (Chapter 16 refers).
Control measures during use	Local shielding (e.g. lead rubber) is to be applied wherever practicable to reduce the dose to personnel working for long periods in close proximity to engines or other components containing thoriated alloys. Rubber gloves are to be worn, where practicable, during routine handling of these items. Small scale drilling or refurbishment can be undertaken with operator wearing suitable RPE and gloves but a strict clean up must be followed on completion. The advice of the RPA must be sought where more major work involving machining or refurbishment of corroded components is required. Standard control measures for work involving contamination are to be followed (see Chapter 4). Components found to have loose surface activity are to be double bagged and advice taken on their decontamination or disposal.

Accounting	These items are to be accounted for on a Radioactive Source List or in equivalent locally produced documentation. Chapter 9 refers.
EPR16/EASR18/RSA93	Thoriated alloy components containing up to 4% w/w thorium are exempt from formal EPR16/EASR18/RSA93 notification to the relevant environment agency but these items are to be included in the Annual Holdings Return to Dstl – Chapter 3 refers. Where components contain more than 4% w/w thorium, notification to the relevant environment agency is required unless the total weight of thorium held on the premises at any one time is 5 kg or below.
Storage and labelling	If uninstalled, these items are to be stored in a dedicated area for radioactive materials – see Chapter 9. Equipment is to display the appropriate radiation warning label on it. The storage/installed area is also to have a sign showing radioactive material within. i.e. a radiation warning trefoil including the contact name and telephone number of the RPS or WPS and stating the nature of the radiological hazard. Larger components can be stored in fire resistant containers or double bagged and stored on metal racking or in an area set aside for their storage. Thoriated aircraft engines are to be stored in conditions which prevent their deterioration, in their transit boxes if practicable and in an area set aside for them.
Contingency Plans / Fire / Contamination / Loss / Incident	In the event of fire, thorium components can oxidise to thorium oxide but both thorium and its oxide are not volatile. Contingency arrangements for a fire involving radioactive material are to be followed (see Chapter 40). Significant contamination is likely to be present on thoriated components affected by the fire. Small amounts of corrosion products or arisings from drilling can be cleaned up using the methods for dealing with breakages outlined in Chapter 40. Reporting of loss and certain other incidents are to be carried out in accordance with procedures described in Chapter 14.
Transport	Items and bulk quantities can be transported within an excepted package provided the dose rate on the external surface of the package does not exceed 5 $\mu Sv\ h^{-1}$ and the item is fully enclosed in an inactive sheath.
Disposal	Small amounts of waste arisings (e.g. from cleanup of contamination) can be disposed of (in an unmarked polythene bag) with ordinary refuse. Equipment containing thoriated alloys incorporating less than 4% w/w thorium can be disposed to a local authority tip. Alternatively, they can be returned to the manufacturer of such equipment, through a MOD establishment or to an external contractor having an authorisation to dispose of thorium waste. There is no limit to the amount of thorium alloy that can be disposed from a premise provided thee is less than 4% thorium by mass. In general, thoriated alloys have been found to be below 4% w/w thorium but, where possible, clarification is to be sought from the manufacturer or Delivery Team, or otherwise from the RPA.

Thoriated Lenses – Hazard and Risk Information

Thoriated Lenses	
Description	Thorium oxide ($Th0_2$) can be added to molten glass during lens manufacture to promote its optical quality. These lenses, termed homogenous thorium oxide lenses, have been found to contain up to 17% w/w thorium. Germanium lenses, for example those used in thermal imaging equipment, can be coated with thorium fluoride (ThF_4) to reduce surface reflections.
Radionuclide	Th-232 and 10 radioactive daughter products including Ra-228, Th-228, Ra-224 and Rn-220.
Ionising radiation	Alpha, beta and gamma radiation from mix of parent and daughter nuclides.
Half life	1.4×10^{10} years (Th-232).
Activity	Homogenous thorium oxide lenses, containing 17% Th-232 w/w, contain approximately 0.7 kBq g^{-1} of Th-232 and up to 6.5 kBq g^{-1} of daughter products. Thorium fluoride coated lenses contain a total of between 0.8 and 3.3 kBq of Th-232 thinly coated around the lens surface plus between 7 and 30 kBq of daughter products.
External radiation hazard	Gamma radiation is emitted from thoriated lenses, beta radiation from layers within a few mm of the surface and alpha radiation from the immediate surface layer. Homogenous thorium oxide lenses (17% w/w) give external beta/gamma dose rates of ~ 100 µSv h^{-1} and for an eye placed close to an unprotected lens, ~ 3 mSv h^{-1} alpha dose rate to the surface of the cornea. Thorium fluoride coated lenses can only give up to a few µSv h^{-1} beta/gamma dose rate but, as above, can give an alpha dose rate to the cornea of ~ 3 mSv h^{-1}. Dose rates fall off rapidly with distance such that significant exposure is only likely for those who work in close proximity for extended periods or those handling bulk quantities.
Internal radiation hazard	The internal hazard from homogenous thorium oxide lenses is negligible unless breakage occurs and shards of glass penetrate the skin, leading to only a minor hazard to the local tissue (due to the insolubility of the thorium oxide present in the glass). Thorium fluoride coatings, on the other hand, are prone to flaking leading to contamination which could potentially be taken into the body. Additionally, a shard of glass from a breakage could penetrate the skin leading to uptake of soluble thorium fluoride and a more significant internal radiation dose, possibly of the order of 1 mSv.
Local orders	Details of the control measures taken from this Chapter are to be included in the local orders for radiation safety (Chapter 16 refers).
Control measures during use	Rubber gloves are to be worn, where practicable, during routine handling of these items, particularly thorium fluoride coated lenses. If thoriated lenses must be used for eye-pieces, they are to be covered with a thin sheet of glass or Perspex to minimise the alpha and beta radiation dose to the eye.

Accounting	These items are to be accounted for on a Radioactive Source List or in equivalent locally produced documentation. Chapter 9 refers.
EPR16/EASR18/RSA 93	Holdings of small quantities of lenses are exempt from notification providing the total weight of thorium at the premises at any one time is 5 kg or below. These items are to be included in the Annual Holdings Return to Dstl – Chapter 3 refers.
Storage and Labelling	Equipment containing thorium lenses are to be marked with a radiation warning trefoil sign unless this is not possible for operational or safety reasons. When uninstalled, these items are to be stored in a dedicated area for radioactive materials – see Chapter 9. The storage/installed area is also to have a sign showing radioactive material within, i.e. a radiation warning trefoil including the contact name and telephone number of the RPS or WPS and stating the nature of the radiological hazard. Strong metal, fire resistant storage cabinets can be used, marked as above providing no more than 400 lenses are contained within and the dose rate on the exterior of the cabinet is < 2.5 µSv h^{-1}.
Contingency Plans / Fire / Breakage / **Loss / Incident**	In the event of fire, thoriated lenses are unlikely to lead to an airborne hazard but there may be some spread of surface contamination. Contingency arrangements for a fire involving radioactive material are to be followed (see Chapter 40). Breakage is to be dealt with by using the methods outlined for dealing with breakages at Chapter 40. Glass fragments entering the skin are to be removed immediately and the wound cleaned under running water – RPA and medical advice is to be sought. RPA advice is to be sought regarding disposal of the arisings from clean up. Reporting of loss and certain other incidents is to be carried out in accordance with procedures described in Chapter 14.
Transport	Items and bulk quantities can be transported within an excepted package provided the dose rate on the external surface of the package does not exceed 5 µSv h^{-1} and the item is fully enclosed in an inactive sheath.
Disposal	Thoriated lenses or fragments of lenses can be disposed of to a local authority tip providing that the total weight of thorium does not exceed 0.5kg in any week. Alternatively, they can be returned to the manufacturer of such equipment, through a MOD establishment or to an external contractor having an authorisation to dispose of thorium waste. For larger quantities, the RPA is to be consulted.

Thoriated Welding Electrodes – Hazard and Risk Information

Thoriated Welding Electrodes	
Description and activity	Thoriated tungsten welding electrodes are still used in plasma cutting and welding processes but are generally now being replaced by non-radioactive electrodes. The non-radioactive variants are to be used wherever practicable. Thoriated welding electrodes typically contain up to a maximum of ~ 7 kBq of Th-232. **The information below is based on the upper bound of 7 kBq per electrode.**
Radionuclide	Th-232 and 10 radioactive daughter products including Ra-228, Th-228, Ra-224 and Rn-220.
Ionising radiation	Alpha, beta and gamma radiation from mix of parent and daughter nuclides.
Half life	1.4 x 10^{10} years (Th-232).
External radiation hazard	The contact dose rate from an electrode is ~ 1 μSv h^{-1} falling off rapidly with distance.
Internal radiation hazard	Despite the high temperatures generated, welding and cutting processes produce only very small quantities of loose airborne or surface radioactivity. Grinding and regrinding of electrode tips, on the other hand, does lead to the production of loose airborne and surface contamination. Potential committed effective doses from grinding operations in the absence of control measures (see below) are estimated as follows: Inhalation of dust up to 5 μSv per grinding activity. Ingestion via contamination transferred from hand to mouth < 1 μSv per grinding activity. Injection through a wound or skin abrasion 7 μSv. **All of the above doses can be substantially reduced by following the control measures (below).**
Local orders	Details of the control measures taken from this Chapter are to be included in the local safety orders or radiation safety orders if held (Chapter 16 refers).
Control measures during use	Use non thoriated welding electrodes wherever practicable. Keep non-essential personnel clear of welding and grinding activities – no eating, drinking smoking rule in place in areas where welding or grinding takes place. Wherever practicable, a grinding wheel is to be reserved for the grinding of thoriated electrodes, local exhaust ventilation is to be provided at the site of the grinding wheel; welders are to wear suitable gloves to prevent grinding dust coming into contact with the skin and wash hands thoroughly after grinding is complete. Any cuts or wounds are to be covered before carrying out grinding operations. Any cuts becoming contaminated with grinding dust are to be allowed to bleed and thoroughly washed in running water.

Thoriated Welding Electrodes	
Control measures during use (continued)	In areas where more than 50 grinding operations per week are undertaken, and in units where training is carried out, in addition to extractors venting to the external atmosphere, surface dust is to be frequently removed using a vacuum cleaner fitted with an absolute dust filter. The vacuum cleaner is to be kept solely for the removal of thorium dust and is to be marked with a radiation warning label. Removal of the dust collection bag or replacement of the absolute filter is to be carried out in accordance with local orders and procedures (using adequately trained personnel wearing gloves, coverall and respiratory protection). In areas where less than 50 grinding operations a week take place, a routine clean-up programme is to be adopted. The grinding dust is to be dampened down and then removed using a damp cloth. The cloth is to be placed in a plastic bag or container displaying no radiation markings and disposed of with normal refuse.
Accounting	These items are to be accounted for on a Radioactive Source List or in equivalent locally produced documentation. Chapter 9 refers. These items are to also be included in the Annual Holdings Return to Dstl – Chapter 3 refers.
EPR16/EASR18/RSA 93	These items are exempt from notification under EPR10/EASR18/RSA93.
Storage and labelling	The number of welding electrodes held in a welding store is to be kept to a minimum. When not in use welding electrodes other than those fitted into arc welding equipment are to be segregated from non-radioactive items and are to be stored together in bundles in a drawer, a locked steel cabinet or metal container. The container is to be marked with a radiation warning sign. The number of welding electrodes held outside the store is to be kept to a minimum and is not to exceed one month's supply where practicable.
Contingency Plans / Fire / Loss / Incident	In the event of fire in a welding shop, it is extremely unlikely that any release of radioactive material will occur from the welding electrodes. Loss of a small number of these consumable electrodes need not be reported. However, if more than 10 electrodes are involved, reporting procedures described in Chapter 14 are to be followed.
Transport	Items and bulk quantities can be transported within an excepted package provided the dose rate on the external surface of the package does not exceed 5 $\mu Sv\ h^{-1}$.
Disposal	Arisings from grinding operations are to be placed in a plastic bag or container displaying no radiation markings and disposed of with normal refuse.