

WASTE STREAM**7G103****LLW from Decommissioned Submarines****SITE** Rosyth & Devonport (Submarines)**SITE OWNER** Ministry of Defence**WASTE CUSTODIAN** Babcock and Ministry of Defence**WASTE TYPE** LLW**WASTE VOLUMES**

Reported

Stocks:	At 1.4.2019.....	0 m ³
Future arisings -	1.4.2019 - 31.3.2020.....	~14.9 m ³
	1.4.2020 - 31.3.2021.....	~7.4 m ³
	1.4.2021 - 31.3.2022.....	~7.4 m ³
	1.4.2022 - 31.3.2023.....	~14.9 m ³
	1.4.2023 - 31.3.2024.....	~14.9 m ³
	1.4.2024 - 31.3.2025.....	~14.9 m ³
	1.4.2025 - 31.3.2026.....	~14.9 m ³
	1.4.2026 - 31.3.2027.....	~14.9 m ³
	1.4.2027 - 31.3.2028.....	~14.9 m ³
	1.4.2028 - 31.3.2029.....	~14.9 m ³
	1.4.2029 - 31.3.2030.....	~0 m ³
	1.4.2030 - 31.3.2031.....	~0 m ³
	1.4.2031 - 31.3.2032.....	~0 m ³
	1.4.2032 - 31.3.2033.....	~14.9 m ³
	1.4.2033 - 31.3.2034.....	~11.1 m ³
	1.4.2034 - 31.3.2035.....	~14.9 m ³
	1.4.2035 - 31.3.2036.....	~11.1 m ³
	1.4.2036 - 31.3.2037.....	~14.9 m ³
	1.4.2037 - 31.3.2038.....	~11.1 m ³
	1.4.2038 - 31.3.2039.....	~11.1 m ³
	1.4.2039 - 31.3.2040.....	~14.9 m ³
	1.4.2040 - 31.3.2041.....	~11.1 m ³
	1.4.2041 - 31.3.2042.....	~14.9 m ³
	1.4.2042 - 31.3.2043.....	~11.1 m ³
	1.4.2043 - 31.3.2044.....	~14.9 m ³
	1.4.2044 - 31.3.2045.....	~11.1 m ³
	1.4.2045 - 31.3.2046.....	~11.1 m ³
	1.4.2046 - 31.3.2047.....	~14.9 m ³
	1.4.2047 - 31.3.2048.....	~11.1 m ³
	1.4.2048 - 31.3.2049.....	~14.9 m ³
	1.4.2049 - 31.3.2050.....	~11.1 m ³
	1.4.2050 - 31.3.2051.....	~14.9 m ³
	1.4.2051 - 31.3.2052.....	~11.1 m ³
	1.4.2052 - 31.3.2053.....	~11.1 m ³
	1.4.2053 - 31.3.2054.....	~14.9 m ³
	1.4.2054 - 31.3.2055.....	~14.9 m ³
	1.4.2055 - 31.3.2056.....	~14.9 m ³
	1.4.2056 - 31.3.2057.....	~0 m ³
	1.4.2057 - 31.3.2058.....	~22.3 m ³
	1.4.2058 - 31.3.2059.....	~0 m ³
	1.4.2059 - 31.3.2060.....	~22.3 m ³
	1.4.2060 - 31.3.2061.....	~0 m ³
	1.4.2061 - 31.3.2062.....	~22.3 m ³
	1.4.2062 - 31.3.2063.....	~0 m ³
	1.4.2063 - 31.3.2064.....	~22.3 m ³
	1.4.2064 - 31.3.2065.....	~0 m ³
	1.4.2065 - 31.3.2066.....	~22.3 m ³
	1.4.2066 - 31.3.2067.....	~0 m ³
	1.4.2067 - 31.3.2068.....	~22.3 m ³
	1.4.2068 - 31.3.2069.....	~0 m ³

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1.4.2069 - 31.3.2070.....	~22.3 m ³
1.4.2070 - 31.3.2071.....	~0 m ³
1.4.2071 - 31.3.2072.....	~22.3 m ³
1.4.2072 - 31.3.2073.....	~0 m ³
1.4.2073 - 31.3.2074.....	~22.3 m ³
1.4.2074 - 31.3.2075.....	~0 m ³
1.4.2075 - 31.3.2076.....	~22.3 m ³
1.4.2076 - 31.3.2077.....	~0 m ³
1.4.2077 - 31.3.2078.....	~22.3 m ³
1.4.2078 - 31.3.2079.....	~0 m ³
1.4.2079 - 31.3.2080.....	~22.3 m ³
1.4.2080 - 31.3.2081.....	~0 m ³
1.4.2081 - 31.3.2082.....	~22.3 m ³
1.4.2082 - 31.3.2083.....	~0 m ³
1.4.2083 - 31.3.2084.....	~22.3 m ³
1.4.2084 - 31.3.2085.....	~0 m ³
1.4.2085 - 31.3.2086.....	~22.3 m ³
1.4.2086 - 31.3.2087.....	~0 m ³
1.4.2087 - 31.3.2088.....	~22.3 m ³
1.4.2088 - 31.3.2089.....	~0 m ³
1.4.2089 - 31.3.2090.....	~22.3 m ³
1.4.2090 - 31.3.2091.....	~0 m ³
1.4.2091 - 31.3.2092.....	~22.3 m ³
1.4.2092 - 31.3.2093.....	~0 m ³
1.4.2093 - 31.3.2094.....	~22.3 m ³
1.4.2094 - 31.3.2095.....	~0 m ³
1.4.2095 - 31.3.2096.....	~22.3 m ³
1.4.2096 - 31.3.2097.....	~0 m ³
1.4.2097 - 31.3.2098.....	~22.3 m ³
1.4.2098 - 31.3.2099.....	~0 m ³
1.4.2099 - 31.3.2100.....	~22.3 m ³
1.4.2100 - 31.3.2101.....	~0 m ³
1.4.2101 - 31.3.2102.....	~22.3 m ³
1.4.2102 - 31.3.2103.....	~0 m ³
1.4.2103 - 31.3.2104.....	~22.3 m ³
1.4.2104 - 31.3.2105.....	~0 m ³
1.4.2105 - 31.3.2106.....	~22.3 m ³
1.4.2106 - 31.3.2107.....	~0 m ³
1.4.2107 - 31.3.2108.....	~22.3 m ³
1.4.2108 - 31.3.2109.....	~0 m ³
1.4.2109 - 31.3.2110.....	~22.3 m ³

Total future arisings: 1047.1 m³

Total waste volume: 1047.1 m³

Comment on volumes: Existing stock is zero. Radioactive material within laid-up submarines is not categorised as waste until dismantling commences. The rate of arising will be determined by the submarine decommissioning project programme schedule. The assumption thereafter is that, as the UK Submarine programme is a rolling one, a submarine will be decommissioned every other year up until the programme end date, producing approximately 22m³ of LLW material per submarine. LLW arising rate is based on the Submarine Dismantling Project's programme scope of decommissioning 27 nuclear submarines, plus future classes. Reactor decommissioning will comprise removal and storage of reactor pressure vessels (RPV) for a 20 year period pending availability of the GDF. Upper/lower bound based on uncertainty over the waste classification of certain plant items. Raw waste volumes are quoted above.

Uncertainty factors on volumes: Stock (upper): x Arisings (upper) x 1.5
 Stock (lower): x Arisings (lower) x 0.6

WASTE SOURCE Dismantling of nuclear steam-raising plant.

PHYSICAL CHARACTERISTICS

General description: The waste is composed of PWR primary circuit components that are contaminated with

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activated crud, together with activated structural steel from the pressure hull and reactor compartment bulkhead. Size reduction of components will be performed to achieve configuration that is compatible with standard disposal containers.

Physical components (%wt): Primary circuit vessels, pumps etc. (45%); steam generators and mounts (30%); Primary Shield Tank structure (10%); misc. reactor compartment components (15%)

Sealed sources: The waste does not contain sealed sources.

Bulk density (t/m³): ~7.9

Comment on density: Quoted density is that of stainless steel.

CHEMICAL COMPOSITION

General description and components (%wt): Stainless steel and ferrous metal (100%wt).

Chemical state: Neutral

Chemical form of radionuclides:
 H-3: Present in Steel.
 C-14: Present in Steel.
 Cl-36: Not present.
 Se-79: Not present.
 Tc-99: Present in Steel.
 I-129: Not present.

Metals and alloys (%wt): Steel plate 6% - thickness approximately 50mm; steel plate 4% - thickness 25mm; stainless steel 85% - pipework outside diameters approximately 13mm to 360mm. Low alloy steel (5%) pipework outside diameters 13mm to 360mm.

Stainless steel.....	~90.0	Stainless steel: C <0.08%; Si >0.2<0.8%; Cr >16.25 <17.5%; Ni >11<13%; Mn<2%; Co <0.05%; Ta <0.03%; P <0.035%; S <0.03%; N <0.08%; Mo >2<2.7%; Fe balance.
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Other ferrous metals.....	~10.0	Structural (low alloy) steel: C <0.15%; Si <0.3%; Mn <1.2%; Ni <1.2%; Mo <0.5%; V <0.12%; S <0.04%; P <0.03%.
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Iron.....	
Aluminium.....	0
Beryllium.....	0
Cobalt.....	TR
Copper.....	TR
Lead.....	0
Magnox/Magnesium.....	0
Nickel.....	0
Titanium.....	0
Uranium.....	0
Zinc.....	0
Zircaloy/Zirconium.....	TR
Other metals.....	0

Organics (%wt):

-	
Total cellulose.....	0
Paper, cotton.....	0
Wood.....	0
Halogenated plastics	0
Total non-halogenated plastics.....	0
Condensation polymers.....	0

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	Others.....	0
	Organic ion exchange materials....	0
	Total rubber.....	0
	Halogenated rubber	0
	Non-halogenated rubber.....	0
	Hydrocarbons.....	
	Oil or grease	
	Fuel.....	
	Asphalt/Tarmac (cont.coal tar)...	
	Asphalt/Tarmac (no coal tar)....	
	Bitumen.....	
	Others.....	
	Other organics.....	0
Other materials (%wt):	-	
	Inorganic ion exchange materials.	0
	Inorganic sludges and flocs.....	0
	Soil.....	0
	Brick/Stone/Rubble.....	0
	Cementitious material.....	0
	Sand.....	
	Glass/Ceramics.....	0
	Graphite.....	0
	Desiccants/Catalysts.....	
	Asbestos.....	0
	Non/low friable.....	
	Moderately friable.....	
	Highly friable.....	
	Free aqueous liquids.....	0
	Free non-aqueous liquids.....	0
	Powder/Ash.....	0
Inorganic anions (%wt):	No inorganic anions will be present in this waste stream.	
	Fluoride.....	0
	Chloride.....	0
	Iodide.....	0
	Cyanide.....	0
	Carbonate.....	0
	Nitrate.....	0
	Nitrite.....	0
	Phosphate.....	0
	Sulphate.....	0
	Sulphide.....	0
Materials of interest for waste acceptance criteria:	None known.	

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Combustible metals.....	0
Low flash point liquids.....	0
Explosive materials.....	0
Phosphorus.....	0
Hydrides.....	0
Biological etc. materials.....	0
Biodegradable materials.....	0
Putrescible wastes.....	0
Non-putrescible wastes.....	0
Corrosive materials.....	0
Pyrophoric materials.....	0
Generating toxic gases.....	0
Reacting with water.....	0
Active particles.....	0
Soluble solids as bulk chemical compounds.....	0
None known.	

Hazardous substances /
non hazardous pollutants:

Acrylamide.....	
Benzene.....	0
Chlorinated solvents.....	
Formaldehyde.....	
Organometallics.....	
Phenol.....	0
Styrene.....	
Tri-butyl phosphate.....	0
Other organophosphates.....	
Vinyl chloride.....	0
Arsenic.....	0
Barium.....	
Boron.....	0
Cadmium.....	0
Caesium.....	
Selenium.....	0
Chromium.....	0
Molybdenum.....	0
Thallium.....	
Tin.....	0
Vanadium.....	0
Mercury compounds.....	
Others.....	0
Electronic Electrical Equipment (EEE)	
EEE Type 1.....	

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EEE Type 2.....
 EEE Type 3.....
 EEE Type 4.....
 EEE Type 5.....

Complexing agents (%wt):

EDTA.....
 DPTA.....
 NTA.....
 Polycarboxylic acids..... 0
 Other organic complexants.....
 Total complexing agents..... 0

TREATMENT, PACKAGING AND DISPOSAL

Planned on-site / off-site treatment(s):

Treatment	On-site / Off site	Stream volume %
Low force compaction	Off-site	100.0
Supercompaction (HFC)		
Incineration		
Solidification		
Decontamination		
Metal treatment		
Size reduction		
Decay storage		
Recycling / reuse		
Other / various		
None	Off-site	1.0

Comment on planned treatments:

It is planned to consign all metallic LLW for treatment by decontamination/smelting. This return assumes that 1% of the original raw volume of material is returned for encapsulation disposal at LLWR, and the balance released as out of scope of environmental permitting regulations. The volume change factor is based on the assumption that 2.5m³ steel will be loaded in to a THISO container of displacement volume 13m³.

Disposal Routes:

Disposal Route	Stream volume %
Expected to be consigned to the LLW Repository	1.0
Expected to be consigned to a Landfill Facility	
Expected to be consigned to an On-Site Disposal Facility	
Expected to be consigned to an Incineration Facility	
Expected to be consigned to a Metal Treatment Facility	
Expected to be consigned as Out of Scope	99.0
Expected to be recycled / reused	
Disposal route not known	

Upcoming (2019/20-2021/22) Waste Routing (if expected to change from above):

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Disposal Route	Stream volume %		
	2019/20	2020/21	2021/22
Expected to be consigned to the LLW Repository			
Expected to be consigned to a Landfill Facility			
Expected to be consigned to an On-Site Disposal Facility			
Expected to be consigned to an Incineration Facility			
Expected to be consigned to a Metal Treatment Facility			
Expected to be consigned as Out of Scope			
Expected to be recycled / reused			
Disposal route not known			

Waste Packaging for Disposal:

Container	Stream volume %	Waste loading m ³	Number of packages
1/3 Height IP-1 ISO	~1.0	~2.5	5
2/3 Height IP-2 ISO			
1/2 Height WAMAC IP-2 ISO			
1/2 Height IP-2 Disposal/Re-usable ISO			
2m box (no shielding)			
4m box (no shielding)			
Other			

Other information: Loading based on optimum waste grout ratio to comply with container gross weight limit.

Waste Planned for Disposal at the LLW Repository:

Container voidage: Treated waste residue will be loaded in compliance with the LLWR acceptance criteria limit on inaccessible voidage.

Waste Characterisation Form (WCH): The waste meets the LLWR's Waste Acceptance Criteria (WAC). The waste does not have a current WCH.

Waste is transferred to the site licensee, Babcock, who dispose of it via LLWR.

Waste consigned for disposal to LLWR in year of generation: Yes.

Potential for the waste to contain discrete items: Yes - steam generators and primary shield tanks may be categorised as discrete items.

Non-Containerised Waste for In-Vault Grouting:

Stream volume (%): -

Waste stream variation: -

Bounding cuboidal volume:

Inaccessible voidage: -

Other information: Primary shield tanks may be consigned for non-containerised in-vault disposal

RADIOACTIVITY

Source: PWR primary circuit components contaminated by activated crud, together with activated structural steel components.

Uncertainty: ATTILA and CAIRN computer codes were used to model neutron fluxes for representative cores and operating histories. The flux modelling code was validated to within $\pm 30\%$ of measured values. Taking account of uncertainty in nuclear data, material composition and reactor power history increases this uncertainty to an overall value of $\pm 50\%$. CRUD deposition within primary circuit components was modelled using the Rolls Royce CRUD code, for which a factor of two is applied for worst-case scenario assessment.

Definition of total alpha and total beta/gamma: Where totals are shown on the table of radionuclide activities they are the sums of the listed alpha or beta/gamma emitting radionuclides plus 'other alpha' or 'other beta/gamma'.

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Measurement of radioactivities:

ATTILA and CAIRN computer codes were used to model neutron fluxes for representative cores and operating histories. CRUD deposition within primary circuit components was modelled using the Rolls Royce CRUD code. Material specifications, impurity levels and neutron fluxes were taken from manufacturer's data, safety justification studies and other available data sources.

Other information:

Activity forecast is based on the raw waste volume.

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Nuclide	Mean radioactivity, TBq/m ³				Nuclide	Mean radioactivity, TBq/m ³			
	Waste at 1.4.2019	Bands and Code	Future arisings	Bands and Code		Waste at 1.4.2019	Bands and Code	Future arisings	Bands and Code
H 3					Gd 153				
Be 10					Ho 163				
C 14			-5.12E-05	AB 2	Ho 166m				
Na 22					Tm 170				
Al 26					Tm 171				
Cl 36					Lu 174				
Ar 39					Lu 176				
Ar 42					Hf 178n				
K 40					Hf 182				
Ca 41					Pt 193				
Mn 53					Tl 204				
Mn 54			-2.23E-10	AB 2	Pb 205				
Fe 55			-9.9E-04	AB 2	Pb 210				
Co 60			-1.54E-03	AB 2	Bi 208				
Ni 59			-3.11E-05	AB 2	Bi 210m				
Ni 63			-3.08E-03	AB 2	Po 210				
Zn 65					Ra 223				
Se 79					Ra 225				
Kr 81					Ra 226				
Kr 85					Ra 228				
Rb 87					Ac 227				
Sr 90					Th 227				
Zr 93			-1.95E-13	AB 2	Th 228				
Nb 91					Th 229				
Nb 92					Th 230				
Nb 93m			-1.5E-07	AB 2	Th 232				
Nb 94			-3.52E-11	AB 2	Th 234				
Mo 93			-9.49E-07	AB 2	Pa 231				
Tc 97					Pa 233				
Tc 99			-1.39E-08	AB 2	U 232				
Ru 106					U 233				
Pd 107					U 234				
Ag 108m					U 235				
Ag 110m					U 236				
Cd 109					U 238				
Cd 113m					Np 237				
Sn 119m			-1.32E-12	AB 2	Pu 236				
Sn 121m			-2.98E-06	AB 2	Pu 238				
Sn 123					Pu 239				
Sn 126					Pu 240				
Sb 125			-5.71E-08	AB 2	Pu 241				
Sb 126					Pu 242				
Te 125m					Am 241				
Te 127m					Am 242m				
I 129					Am 243				
Cs 134					Cm 242				
Cs 135					Cm 243				
Cs 137					Cm 244				
Ba 133					Cm 245				
La 137					Cm 246				
La 138					Cm 248				
Ce 144					Cf 249				
Pm 145					Cf 250				
Pm 147					Cf 251				
Sm 147					Cf 252				
Sm 151					Other a				
Eu 152					Other b/g		-1.57E-12	AB 2	
Eu 154					Total a	0	0		
Eu 155					Total b/g	0	-5.70E-03	AB 2	

Bands (Upper and Lower)

- A a factor of 1.5
- B a factor of 3
- C a factor of 10
- D a factor of 100
- E a factor of 1000

Note: Bands quantify uncertainty in mean radioactivity.

Code

- 1 Measured activity
- 2 Derived activity (best estimate)
- 3 Derived activity (upper limit)
- 4 Not present
- 5 Present but not significant
- 6 Likely to be present but not assessed
- 7 Present in significant quantities but not determined
- 8 Not expected to be present in significant quantity