

WASTE STREAM	7G104	Long-Lived ILW from Decommissioned Submarines
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SITE Rosyth & Devonport (Submarines)

SITE OWNER Ministry of Defence

WASTE CUSTODIAN Babcock and Ministry of Defence

WASTE TYPE ILW

WASTE VOLUMES

		Reported
Stocks:	At 1.4.2019.....	0 m ³
Future arisings -	1.4.2019 - 31.3.2020.....	0 m ³
	1.4.2020 - 31.3.2021.....	1.6 m ³
	1.4.2021 - 31.3.2022.....	1.6 m ³
	1.4.2022 - 31.3.2023.....	0 m ³
	1.4.2023 - 31.3.2024.....	0 m ³
	1.4.2024 - 31.3.2025.....	1.1 m ³
	1.4.2025 - 31.3.2026.....	2.1 m ³
	1.4.2026 - 31.3.2027.....	2.1 m ³
	1.4.2027 - 31.3.2028.....	2.1 m ³
	1.4.2028 - 31.3.2029.....	2.1 m ³
	1.4.2029 - 31.3.2030.....	3.2 m ³
	1.4.2030 - 31.3.2031.....	3.2 m ³
	1.4.2031 - 31.3.2032.....	3.2 m ³
	1.4.2032 - 31.3.2033.....	2.1 m ³
	1.4.2033 - 31.3.2034.....	1.6 m ³
	1.4.2034 - 31.3.2035.....	2.1 m ³
	1.4.2035 - 31.3.2036.....	1.6 m ³
	1.4.2036 - 31.3.2037.....	2.1 m ³
	1.4.2037 - 31.3.2038.....	1.6 m ³
	1.4.2038 - 31.3.2039.....	1.6 m ³
	1.4.2039 - 31.3.2040.....	2.1 m ³
	1.4.2040 - 31.3.2041.....	1.6 m ³
	1.4.2041 - 31.3.2042.....	2.1 m ³
	1.4.2042 - 31.3.2043.....	1.6 m ³
	1.4.2043 - 31.3.2044.....	2.1 m ³
	1.4.2044 - 31.3.2045.....	1.6 m ³
	1.4.2045 - 31.3.2046.....	1.6 m ³
	1.4.2046 - 31.3.2047.....	2.1 m ³
	1.4.2047 - 31.3.2048.....	1.6 m ³
	1.4.2048 - 31.3.2049.....	2.1 m ³
	1.4.2049 - 31.3.2050.....	1.6 m ³
	1.4.2050 - 31.3.2051.....	2.1 m ³
	1.4.2051 - 31.3.2052.....	1.6 m ³
	1.4.2052 - 31.3.2053.....	1.6 m ³
	1.4.2053 - 31.3.2054.....	2.1 m ³
	1.4.2054 - 31.3.2055.....	2.1 m ³
	1.4.2055 - 31.3.2056.....	2.1 m ³
	1.4.2056 - 31.3.2057.....	0 m ³
	1.4.2057 - 31.3.2058.....	3.2 m ³
	1.4.2058 - 31.3.2059.....	0 m ³
	1.4.2059 - 31.3.2060.....	3.2 m ³
	1.4.2060 - 31.3.2061.....	0 m ³
	1.4.2061 - 31.3.2062.....	4.7 m ³
	1.4.2062 - 31.3.2063.....	0 m ³
	1.4.2063 - 31.3.2064.....	4.7 m ³
	1.4.2064 - 31.3.2065.....	0 m ³
	1.4.2065 - 31.3.2066.....	4.7 m ³
	1.4.2066 - 31.3.2067.....	0 m ³
	1.4.2067 - 31.3.2068.....	4.7 m ³
	1.4.2068 - 31.3.2069.....	0 m ³

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1.4.2069 - 31.3.2070.....	4.7 m ³
1.4.2070 - 31.3.2071.....	0 m ³
1.4.2071 - 31.3.2072.....	4.7 m ³
1.4.2072 - 31.3.2073.....	0 m ³
1.4.2073 - 31.3.2074.....	4.7 m ³
1.4.2074 - 31.3.2075.....	0 m ³
1.4.2075 - 31.3.2076.....	4.7 m ³
1.4.2076 - 31.3.2077.....	0 m ³
1.4.2077 - 31.3.2078.....	4.7 m ³
1.4.2078 - 31.3.2079.....	0 m ³
1.4.2079 - 31.3.2080.....	4.7 m ³
1.4.2080 - 31.3.2081.....	0 m ³
1.4.2081 - 31.3.2082.....	4.7 m ³
1.4.2082 - 31.3.2083.....	0 m ³
1.4.2083 - 31.3.2084.....	4.7 m ³
1.4.2084 - 31.3.2085.....	0 m ³
1.4.2085 - 31.3.2086.....	4.7 m ³
1.4.2086 - 31.3.2087.....	0 m ³
1.4.2087 - 31.3.2088.....	4.7 m ³
1.4.2088 - 31.3.2089.....	0 m ³
1.4.2089 - 31.3.2090.....	4.7 m ³
1.4.2090 - 31.3.2091.....	0 m ³
1.4.2091 - 31.3.2092.....	4.7 m ³
1.4.2092 - 31.3.2093.....	0 m ³
1.4.2093 - 31.3.2094.....	4.7 m ³
1.4.2094 - 31.3.2095.....	0 m ³
1.4.2095 - 31.3.2096.....	4.7 m ³
1.4.2096 - 31.3.2097.....	0 m ³
1.4.2097 - 31.3.2098.....	4.7 m ³
1.4.2098 - 31.3.2099.....	0 m ³
1.4.2099 - 31.3.2100.....	4.7 m ³
1.4.2100 - 31.3.2101.....	0 m ³
1.4.2101 - 31.3.2102.....	4.7 m ³
1.4.2102 - 31.3.2103.....	0 m ³
1.4.2103 - 31.3.2104.....	4.7 m ³
1.4.2104 - 31.3.2105.....	0 m ³
1.4.2105 - 31.3.2106.....	4.7 m ³
1.4.2106 - 31.3.2107.....	0 m ³
1.4.2107 - 31.3.2108.....	4.7 m ³
1.4.2108 - 31.3.2109.....	0 m ³
1.4.2109 - 31.3.2110.....	4.7 m ³

Total future arisings: 191.5 m³

Total waste volume: 191.5 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 end date included in this data sheet of approximately 3.16576 m³ of ILW-characterised material per submarine for PWR1 and approximately 4.74864 m³ of ILW-characterised material per submarine for PWR2. The expected increase in approximated arisings is thought to be minimal - e.g. equipment being used to remove the contaminated waste. ILW arising rate is based on the Submarine Dismantling Project's programme for the decommissioning of 27 nuclear submarines in scope along with any additional future classes. Reactor decommissioning will comprise removal and storage of reactor pressure vessels (RPV) for a 20 year period pending availability of the GDF. Volume figures are based on the raw volume of stainless steel wastes, assuming a density of 7.9 g/cc. Volume uncertainty figures are based on the upper and lower estimates of waste mass, which is dependent on the strategy for dismantling the reactor pressure vessel (RPV) and segregating the resultant wastes. Studies indicate that each submarine would yield between 19 and 47 te of ILW; this forecast is based on the baseline assumption of 25 te of ILW per submarine.

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Uncertainty factors on volumes:	Stock (upper): x	Arisings (upper) x 1.88
	Stock (lower): x	Arisings (lower) x 0.79

WASTE SOURCE Decommissioning of the UK fleet of nuclear powered submarines.

PHYSICAL CHARACTERISTICS

General description: The waste consists of high grade structural steel arising from dismantling of reactor pressure vessel components. Size reduction of components will be performed to achieve a configuration that is compatible with standard ILW disposal containers.

Physical components (%wt): Thermal shields (74%), reactor core barrel (20%) and RPV SS cladding (6%).

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): Steel (100%). Thermal shield assembly and RPV cladding consist of austenitic stainless steel; core barrel of approx. 1/2 austenitic stainless steel, 1/2 low alloy steel.

Chemical state: Neutral

Chemical form of radionuclides:

- H-3: Present in Steel
- C-14: Present in Steel
- Cl-36: None present
- Se-79: None present
- Tc-99: Present in Steel
- I-129: None present

Metals and alloys (%wt): RPV 60%. Core barrel 5%. 1st thermal shield 3%. 2nd thermal shield 5%. 3rd thermal shield 15%. Thermal shield support 5%. Primary shield tank 7%.

Stainless steel.....	~89.6	Austenitic 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.
Other ferrous metals.....	~10.0	Upper section of core barrel is low alloy steel: C>0.13<0.18%; Mn>1.15<1.55%; Mo>0.41<0.64%; Ni>0.6<0.83%; Si>0.13<0.32%.
Iron.....		
Aluminium.....	~0	
Beryllium.....	~0	
Cobalt.....	~0	
Copper.....		
Lead.....	~0	
Magnox/Magnesium.....	~0	
Nickel.....	~0	
Titanium.....		
Uranium.....	~0	
Zinc.....	~0	
Zircaloy/Zirconium.....	~0	
Other metals.....	~0.40	The total of Cr, V, Ni and Ti <0.2%; S, P, Cu, Sn and As <0.18%.

Organics (%wt): None

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	Total celluloseics.....	0
	Paper, cotton.....	0
	Wood.....	0
	Halogenated plastics	0
	Total non-halogenated plastics.....	0
	Condensation polymers.....	0
	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.....	0
	Glass/Ceramics.....	0
	Graphite.....	0
	Desiccants/Catalysts.....	0
	Asbestos.....	0
	Non/low friable.....	
	Moderately friable.....	
	Highly friable.....	
	Free aqueous liquids.....	0
	Free non-aqueous liquids.....	0
	Powder/Ash.....	0
Inorganic anions (%wt):	There is no evidence of inorganic anions in this waste stream.	

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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:

-	
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

Hazardous substances / non hazardous pollutants:

None	
Acrylamide.....	
Benzene.....	0
Chlorinated solvents.....	
Formaldehyde.....	
Organometallics.....	
Phenol.....	0
Styrene.....	
Tri-butyl phosphate.....	0
Other organophosphates.....	
Vinyl chloride.....	0
Arsenic.....	0
Barium.....	
Boron.....	0

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

Complexing agents (%wt): No
 EDTA.....
 DPTA.....
 NTA.....
 Polycarboxylic acids..... 0
 Other organic complexants..... 0
 Total complexing agents..... 0

PACKAGING AND CONDITIONING

Conditioning method: None planned.
 Plant Name: -
 Location: -
 Plant startup date: -
 Total capacity (m³/y incoming waste): -
 Target start date for packaging this stream: -
 Throughput for this stream (m³/y incoming waste): -
 Other information: -

Likely container type:	Container	Waste packaged (%vol)	Waste loading (m ³)	Payload (m ³)	Number of packages
	3m ³ box (square corners)	100.0	~0.28	~2.8	684

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Likely container type comment: 3 cu.m box with displacement volume of 3.6m³. Baseline assumptions of 25te ILW and 11 boxes per submarine yield a loading of 0.29m³ per container with 1.1 m³ usable volume, corresponding to a packing fraction of 0.26 and waste loading of 0.29.

Range in container waste volume: A minimum of 7 and a maximum of 14 3m³ boxes per submarine will be required. Baseline figure used in this forecast is 11 boxes.

Other information on containers: -

Likely conditioning matrix: None

Other information: -

Conditioned density (t/m³): ~0.6

Conditioned density comment: Conditioned density is the mass loaded per container (2.29 te) divided by the container displacement volume (3.6m³).

Other information on conditioning: -

Opportunities for alternative disposal routing: Not yet determined

Treatment	Stream volume (%)	Comment
-	-	-

RADIOACTIVITY

Source: The main source of radioactivity is due to the neutron activation of the steel PWR pressure vessel. Short-lived activity is present in activated corrosion products deposited on the internal surfaces of components within the RPV.

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 ±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 ±50%.

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'.

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: -

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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			~6.74E-02	A B 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			~9.66E-07	A B 2	Pb 205				
Fe 55			~1.97E+00	A B 2	Pb 210				
Co 60			~5.24E+00	A B 2	Bi 208				
Ni 59			~3.05E-01	A B 2	Bi 210m				
Ni 63			~3.13E+01	A B 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					Th 228				
Nb 91					Th 229				
Nb 92					Th 230				
Nb 93m			~8.49E-04	A B 2	Th 232				
Nb 94			~2.73E-05	A B 2	Th 234				
Mo 93			~1.46E-04	A B 2	Pa 231				
Tc 97					Pa 233				
Tc 99			~1.96E-06	A B 2	U 232				
Ru 106					U 233				
Pd 107					U 234				
Ag 108m					U 235				
Ag 110m			~1.58E-11	A B 2	U 236				
Cd 109					U 238				
Cd 113m					Np 237				
Sn 119m			~2.48E-10	A B 2	Pu 236				
Sn 121m			~4.67E-04	A B 2	Pu 238				
Sn 123					Pu 239				
Sn 126					Pu 240				
Sb 125			~1.11E-05	A B 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		~8.88E-11	A B 2	
Eu 154					Total a	0	0		
Eu 155					Total b/g	0	~3.89E+01	A B 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