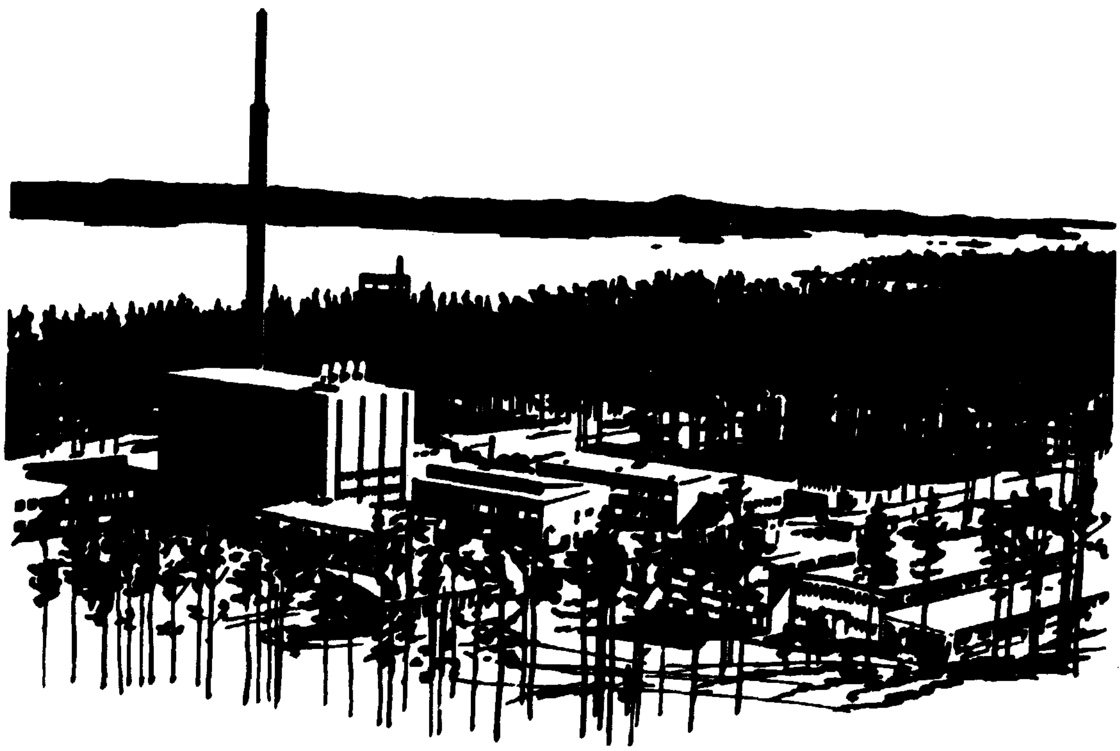
Studsvik Report

STUDSVIK/NW–84/830

THE HANDLING AND DISPOSAL OF FUSION WASTES

Progress report February 1985

Karin Brodén
Åke Hultgren
Gunnar Olsson



STUDSVIK ENERGITEKNIK AB

STUDSVIK/NW-84/830
1984-10-15 First draft
1985-02-01 Final issue

FUTEC S&E3

Karin Brodén
Åke Hultgren
Gunnar Olsson

Energy Research Commission
CEC Association Contract
No. 109-82-1-FUA S
Fusion Technology,
S&E3 Waste Management

THE HANDLING AND DISPOSAL OF FUSION WASTES
Progress report February 1985

SUMMARY

The radioactive wastes from fusion reactor operation will include spent components, wastes from repair operations, and decontamination waste. Various disposal routes may be considered depending on i.e. the contents of tritium and of long-lived nuclides, and on national regulations. The management philosophy and disposal technology developed in Sweden for light water reactor wastes has been studied at STUDSVIK during 1983--84 and found to be applicable also to fusion wastes, provided a detritiation stage is included. These studies will continue during 1985 and include experimental work on selected fusion activation nuclides.

The work presented is associated to the CEC fusion research programme. Valuable discussions and contacts with people working in this programme at Saclay, Ispra and Garching are deeply appreciated.

Åke Hultgren

CONTENTS

1 INTRODUCTION

Considerable quantities of radioactive waste will be generated in the operation of fusion reactors, due to the choice of materials and the replacement frequency for vital components with their limited life expectancy in the reactor. Compared to fission reactor wastes the fusion wastes exhibit a unique combination of highly activated and tritiated materials. An evaluation of possible schemes for their treatment and options for their disposal deserves attention in an early part of the development of fusion power.

Work on the management of fusion wastes in the Swedish fusion research programme as associated to the European Fusion Technology Programme 1982--86 was started at STUDSVIK in 1983.

The general programme plan included the following areas:

1) Identification of generated waste categories, amount of radioactivity, nuclides and volumes.

2) Discussion of feasible waste management strategies for the different waste categories.

3) Identification of key problems (safety and technical) for further assessment.

4) Safety analysis of selected areas of special concern.

5) Conceptual studies of waste handling processes.

The first introductory studies focussed on waste identification and possible strategies for waste management, centred around the Tokamak reactor concept. These studies have continued during 1934, to have better defined source terms for safety assessments and to serve as a basis for waste classification as related to the identification of disposal routes suitable for different waste categories. The classification work uses the strategy developed in Sweden for the disposal of different categories of fission wastes.

The planning for continued work has been expanded to include also experimental safety related studies for start-up during 1985/86. These studies will include migration and sorption laboratory experiments for specific fusion waste radioactive nuclides (e g Mo-93 with Mo-99 as tracer in the experiments) in geologic systems.

Exchange of information and experience with other research centra for this project has been established and will be expanded. Continued studies will use the NET design as the main basis for calculations and design of experiments.

2 WASTE CHARACTERISTICS

Primary fusion reactor waste will mainly include spent components, solid waste from repair operation, and decontamination waste. The radioisotopes in the waste result from neutron activation and tritium contamination.

In the following, Bq and Sv/h are used as units for activity and dose rate, respectively, in our own evaluations and estimates. Material extracted from references is, however, presented in original form and Ci and rem/h have thus not been recalculated to new units here.

2.1 Spent components from the exhaust system, blanket and first wall

Components near the plasma require regular replacement i.a. due to induced radiation damage caused by high energy neutrons. In the NET machine the exhaust system, blanket and first wall form a removable structure. From this structure different components can be removed and replaced with relative rapidity (1).

The NET team in Garching is working with material selections for NET (2). As principal first wall and breeder structural materials two types of steel have been identified on which research and development will be concentrated initially (2):

- AISI 316 austenitic steel
- 1.4914 (10-12 % Cr-Mo-V-Nb) martensitic steel.

As the divertor armour and heat-sink materials 10 % tungsten - 26 % rhenium alloys, and a copper - 0.65 % chromium - 0.08 % zirconium alloy have been chosen (2).

For the tritium breeding materials several options have been proposed (2):

- liquid $Li_{17}Pb_{83}$
- lithium oxide
- lithium aluminate
- lithium silicate
- lithium titanate
- lithium zirconate.

Beryllium is a good neutron multiplier. An adaption to NET has been made of a beryllium canister blanket concept (3). Beryllium has, however, the disadvantage of being very toxic and must therefore be managed by special manipulation (4).

Table 1 shows estimated activities induced in the structural material AISI 316 of a tokamak fusion reactor at shut-down after two years of operation. The table also gives information about the half-lives and the annual limits on intake (ALI) for the produced nuclides.

The specific activity levels at shut-down in the first wall, blanket and divertor in a NET machine, with AISI 316 as first wall material, a blanket with $Li_{17}Pb_{83}$ and tungsten-copper in the divertor, have been estimated to 40-100 Ci/cm^3, 10 Ci/cm^3 (average) and 50 Ci/cm^3, respectively (7). The activity in $Li_{17}Pb_{83}$ is essentially due to its tritium contents. The ALI-value for tritiated water is $3 \cdot 10^9$ Bq. The limit for elemental tritium is more than four orders of magnitude higher (5).

TABLE 1 Induced activities in the structural material stainless steel AISI 316 (63.9 % Fe, 17 % Cr, 12.3 % Ni, 2.5 % Mo, 1.8 % Mn, 1.0 % Cu, 0.5 % Si, 0.25 % Co, 0.15 % Ta) of a tokamak fusion reactor at shut-down after 2 years of operation.

Isotope	Half-life		ALI oral (5) Bq	Induced activity (6) Ci/kW(th)
Mg-27	9.46	min		0.036
Al-28	2.3	min		13.1
Ca-45	165	day	$6 \cdot 10^{7}$	0.01
Sc-46	83.9	day	$3 \cdot 10^{7}$	0.01
Sc-47	3.43	day	$8 \cdot 10^{7}$	0.01
Sc-48	1.83	day	$3 \cdot 10^{7}$	0.02
Ti-51	5.8	min		0.14
V -49	330	day	$3 \cdot 10^{9}$	1.17
V -52	3.75	min		35.4
Cr-51	27.8	day	$1 \cdot 10^{9}$	100
Mn-53	$1.9 \cdot 10^{6}$	yr	$2 \cdot 10^{9}$	$5 \cdot 10^{-6}$
Mn-54	303	day	$7 \cdot 10^{7}$	53.5
Mn-56	2.58	h	$2 \cdot 10^{8}$	352
Mn-57	1.5	min		2.43
Fe-55	2.6	yr	$3 \cdot 10^{8}$	195
Fe-59	45.6	day	$3 \cdot 10^{7}$	0.14
Co-57	270	day	$2 \cdot 10^{8}$	17.4
Co-58	71.3	day	$5 \cdot 10^{7}$	90
Co-60m	10.5	min	$4 \cdot 10^{10}$	10.4
Co-60	5.26	yr	$7 \cdot 10^{6}$	4.8
Ni-57	36	h	$6 \cdot 10^{7}$	3.54
Ni-59	$8 \cdot 10^{4}$	yr	$9 \cdot 10^{8}$	$3 \cdot 10^{-5}$
Ni-63	92	yr	$3 \cdot 10^{8}$	0.036
Sr-89	52.7	day	$2 \cdot 10^{7}$	0.002
Sr-90	27.7	yr	$1 \cdot 10^{6}$	$4 \cdot 10^{-6}$
Zr-89	78.4	h	$6 \cdot 10^{7}$	0.18
Zr-95	65.5	day	$5 \cdot 10^{7}$	0.04
Nb-92m	10.2	day		0.42
Nb-95m	90	h	$8 \cdot 10^{7}$	0.07
Nb-95	35	day	$8 \cdot 10^{6}$	0.21
Nb-96	23.4	h	$4 \cdot 10^{7}$	0.09
Nb-97	72	min	$8 \cdot 10^{8}$	0.065
Mo-91	15.5	min		1.28
Mo-93	$3.5 \cdot 10^{3}$	yr	$1 \cdot 10^{8}$	
Mo-99	66.7	h	$4 \cdot 10^{7}$	28.7
Mo-101	14.6	min	$2 \cdot 10^{9}$	8.3
Tc-99m	6.87	h	$3 \cdot 10^{9}$	28.7
Tc-99	$2.15 \cdot 10^{5}$	yr	$1 \cdot 10^{8}$	$2 \cdot 10^{-4}$
Tc-101	14	min	$3 \cdot 10^{9}$	8.3
Total				1062

The surface dose rate from the first wall at shut- down has been estimated to 10^7 rem/h. This figure will decrease to about 70 % of its initial value after one day and to about 65 % of the initial value after ten days. The dose rate from the divertor will decrease faster; a factor two after one day and a factor ten after ten days with a shut-down dose rate of $2.7 \cdot 10^6$ rem/h (7).

The torus in the INTOR-NET phase 2A design is composed of 12 segments each containing (7):

- a 150 tonnes stainless steel semipermanent part at the toroidal vessel
- a 120 tonnes stainless steel torus support, including the exhaust ducts of the pumping system.
- a 150 tonnes stainless steel and 2.5 m^3 $Li_{17}Pb_{83}$ renewable blanket part
- a 30 tonnes stainless steel renewable divertor cassette.

Components removed from the exhaust system, blanket and first wall would have to be processed for storage or disposal. The treatment procedures will include:

- heat treatment to remove tritium
- dismantling, cutting and compaction
- packaging.

2.2 Solid waste from repair operations

Large amounts of solid low level radioactive waste will be produced at repair operations. The waste will be slightly tritiated and sometimes also activated (4).

2.3 Decontamination waste

It will probably be possible to decrease volumes of decontamination waste considerably by recycling most of aqueous decontamination solutions (4). Documented estimates of decontamination waste arisings vary within wide ranges. Annual waste quantities of oily sludges and aqueous concentrates have been estimated to 2-7 m^3/GWe and 35-100 m^3/GWe, respectively, before solidification. This would correspond to 7-20 m^3/GWe and 70-200 m^3/GWe of solidified waste annually. An elaboration of ways to minimize decontamination waste volumes would thus be of importance.

3 WASTE DISPOSAL OPTIONS

Typical for primary fusion waste is radioactive material with neutron-induced activity in combination with tritium. Due to high initial radioactivity levels and surface dose rates, the stainless steel structures of the first wall and blanket will require gamma shielding comparable to that for spent fuel from fission reactors. The shipping casks will be "type B packaging" and their weight of the order of 100 tonnes. The shielding and transport requirements will have to be considered in the overall handling and disposal strategy.

In the investigations of options for fusion waste disposal it is natural to take advantage of the experience from actual methods being practised or planned for fission waste. The strategy varies, however, somewhat between various nations. Here mainly the Swedish options are referred to.

3.1 Intermediate storage

The half-lives are short for many radioactive nuclides in primary fusion waste. Intermediate storage can therefore be used to decrease the dose rates from spent components (cf section 2.1) before further treatment or to decrease the activity of radioactive parts before their reuse or declassification.

As a retrievable storage facility for activated parts with high dose rates from a fusion power plant, Kaser et al (10), have suggested a shielded tunnel with openings at both ends.

Intermediate storage is a natural application also for fission reactor wastes.

Some examples from Sweden are given in the following:

- At the nuclear power plants treated reactor waste is stored in intermediate stores at the sites. A storage building consisting of separate concrete cells, each with a capacity of 24 drums and with separate fire protection, is used for bituminized waste at Barsebäck. Cemented waste at Ringhals and Oskarshamn is stored above ground in a building with shielding concrete walls and below ground in granite rock, respectively (10).

- Used fuel and core components with high activity will be transported to a central fuel storage facility, CLAB, for intermediate storage under water before it will be sent to a final repository for long-lived radioactive waste (SFL).

- At Studsvik an underground cavity will be used for storage of treated intermediate and low level waste. The waste will then be sent to the final repository for reactor waste SFR or to the SFL-repository.

The underground store at Studsvik and also the intermediate stores at the nuclear power plants in Sweden are built for intermediate storage of waste until the repositories for disposal are available. These types of stores can also be used for low and medium level fusion waste. The surface dose rates on the packages (1 m^3 concrete containers, 200-liter steel drums, steel boxes) are restricted to maximum 0.5 Sv/h (50 rem/h) at the underground store at Studsvik. The limits are lower at the intermediate stores at the nuclear power plants.

The activated fusion waste will contain not only activation products but also large amounts of tritium compared to the tritium content in spent activated components from a fission reactor.

Therefore a storage facility like CLAB would require detritiation of the waste or steps for tritium containment to be suitable for intermediate storage of spent components from a fusion reactor.

3.2 Shallow land burial

Shallow land burial of low- and medium level wastes of various origin has been practised extensively in many countries, e.g. France, United Kingdom and United States, where central burial sites are used.

In Sweden shallow land burial has so far not been allowed. However, the new Swedish law on nuclear activities (11) makes it possible to establish local shallow land burial facilities at nuclear sites, e.g. at a nuclear power plant.

The regulations for central burial sites in various countries give certain limits of special interest in connection with fusion waste.

The US Nuclear Regulatory Commission's requirements for land disposal of radioactive waste are published in 10 CFR (Code of Federal Regulations) Part 61 (12). Waste that is acceptable for near-surface disposal is here divided into three classes; A, B and C. Class A waste is waste that is segregated at the disposal site unless structurally stable. Class B waste is waste that must meet more rigorous requirements on waste form to ensure stability after disposal. Class C waste is waste that not only must meet more rigorous requirements on waste form to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion. The specific activity limits for different radionuclides in class A, B and C waste are shown in Table 2.

TABLE 2. The specific activity limits for different radionuclides in class A, B and C waste (12). See section 3.2 for explanations.

Radionuclide	Specific Activity Limits, Ci/m^3 [1)]		
Long-lived nuclides	Class A	Class C	
C-14	≤ 0.8	0.9-8	
C-14 in activated metal	≤ 8	9-80	
Ni-59 in activated metal	≤ 22	23-220	
Nb-94 in activated metal	≤ 0.02	0.03-0.2	
Tc-99	≤ 0.3	0.4-3	
I-129	≤ 0.008	0.009-0.08	
Alpha emitting transuranic nuclides with half-life greater than five years	≤ 10 nCi/g	20-100 nCi/g	
Pu-241	≤ 350 nCi/g	360-3500 nCi/g	
Cm-242	≤ 2000 nCi/g	3000-20000 nCi/g	
Short-lived nuclides	Class A	Class B	Class C
Total of all nuclides with < 5 year half-life	≤ 700	no limit[2)]	no limit[2)]
H-3	≤ 40	no limit[2)]	no limit[2)]
Co-60	≤ 700	no limit[2)]	no limit[2)]
Ni-63	≤ 3.5	3.6-70	80-700
Ni-63 in activated metal	≤ 35	36-700	800-7000
Sr-90	≤ 0.04	0.05-150	160-7000
Cs-137	< 1	2-44	45-4700

1) If radioactive waste does not contain any nuclides listed in the table it is Class A waste.

2) Practical considerations such as the effects of external radiation and internal heat generation on transportation, handling, and disposal will limit the concentrations.

TABLE 3. Specific activities and corresponding waste classes (cf Table 2) for the first wall and neutron multiplier zone of INTOR, operating time: 10 years (13)

Radionuclide	Half-life yr	Specific Activity Ci/m^3	Waste Class
Fe-55	2.7	$1.7 \cdot 10^7$	B
Co-60	5.3	$1.2 \cdot 10^6$	B
Ni-63	10^2	$2.6 \cdot 10^4$	C
Mo-93	$4 \cdot 10^3$	6.4	A
C-14	$6 \cdot 10^3$	$4.8 \cdot 10$	C
Nb-94	$2 \cdot 10^4$	1.4	1)
Ni-59	$8 \cdot 10^4$	$2.8 \cdot 10^2$	A
Tc-99	$2 \cdot 10^5$	9.0	1)
Mn-53	$4 \cdot 10^6$	$4.3 \cdot 10^{-1}$	A
Pb-205	10^7	2.3	A

1) Not generally acceptable for near-surface disposal.

For classification of waste that contains a mixture of radionuclides it is necessary to determine the sum of fractions by dividing each nuclide concentration by the appropriate limit and adding the resulting values. The appropriate limits must all be taken from the same waste class for the same type of nuclides (long-lived or short-lived). Table 3 shows the specific activities and corresponding waste classes for the first wall and neutron multiplier zone of INTOR conceptual fusion reactor after an operating time of ten years. The Nb-94 and Tc-99 concentrations in this type of waste exceed the limits for waste generally acceptable for near-surface disposal. It should be noted that the specific activity values in waste from other zones of the reactor are lower.

The requirements include no tritium limit for Class B waste. Therefore, other restrictions will limit the concentration (cf Table 2).

Results from a French study on the impact of shallow land burial for waste from fusion reactors shows that Mo-93 is a limiting nuclide for shallow land burial in France (20).

3.3 Shallow geological disposal

In Sweden low- and medium-level operating and decommissioning wastes from reactor operation will be deposited in the disposal facilities SFR 1 and SFR 3 at Forsmark, respectively. The SFR 1 will also be used for operating waste from the CLAB and waste from industry and hospitals which is not regarded as being long-lived (14).

The waste to be deposited in the SFR will vary considerably with regard to both form and radioactive content.

The main types of packages for low-level waste (surface dose rate < 0.1-0.3 mSv/h) will be:

- 200-liter steel drums
- steel boxes
- 7' x 10' or 7' x 20' containers.

The main types of packages for medium-level waste (surface dose rate < 0.03-0.5 Sv/h)) will be:

- 200-liter steel drums
- concrete containers (1 m^3).

The majority of the SFR 1 waste will be deposited in silos in rock. A minor portion of the operating waste in terms of radioactive content (< 10 %) will be deposited in a simpler manner in tunnels in rock vaults (14).

Table 4 shows estimated amounts of some nuclides in blanket waste from a tokamak reactor at shut-down after ten years of operation. The table also shows estimated total amounts of the same nuclides in the SFR 1 and SFR 3 waste. The total activity in the blanket waste from a fusion reactor has been estimated to about 10^{11} GBq at shut-down and 10^{7} GBq after one year (15). The total activity in SFR 1 and SFR 3 will be $6.7 \cdot 10^{6}$ GBq and $3 \cdot 10^{6}$ GBq, respectively, at closing (16). This means that the total activity in the blanket waste from a fusion reactor (5000 MW_{th} tokamak) after 1 year of decay is comparable to the total activity in SFR 1 and SFR 3.

The waste volumes in SFR 1 and SFR 3 will be $1.0 \cdot 10^{5}$ m^3 and $1.4 \cdot 10^{5}$ m^3, respectively (14). The waste from a fusion reactor blanket (8) has been estimated to 10^{3} m^3 (UWMAK-I, 10 years of operation).

TABLE 4 Estimated amounts of some nuclides in fusion blanket waste from a 5 000 MWth Tokamak (UWMAK-I) after 10 years of operation (without storage for decay) compared to maximum amounts of radionuclides in the SFR 1 and SFR 3 wastes at repository closing (14, 15, 16).

	Half-Life Yr	Activity in fusion waste GBq	Activity in SFR 1 waste 1) GBq	Activity in SFR 3 waste 2) GBq
Fe-55	2.6	$3 \cdot 10^8$	$6.3 \cdot 10^5$	$2 \cdot 10^6$
Co-60	5.3	$9 \cdot 10^8$	$1.6 \cdot 10^6$	$7 \cdot 10^5$
Tc-99	$2.2 \cdot 10^5$	$4 \cdot 10^4$	$2.0 \cdot 10^2$	$4 \cdot 10^{-1}$
Ni-63	92	$7 \cdot 10^6$	$4.6 \cdot 10^5$	$1 \cdot 10^5$
Ni-59	$8 \cdot 10^4$	$6 \cdot 10^3$	$5 \cdot 10^3$	$1 \cdot 10^3$
Mo-93	$3.5 \cdot 10^3$	$9 \cdot 10^5$	-	-

1) Reactor operation waste
2) Decommissioning waste

3.4 Deep geological disposal

Deep geological disposal is an expensive disposal method which should be limited to waste that cannot be accepted in less sofisticated types of repository.

The long-lived waste originating from reactor operation and decommissioning in Sweden and from spent fuel reprocessing will be stored in rock vaults 300 m or, alternatively, 500 m below ground level in the repository SFL, according to present planning (14). There will be four types of SFL repository, intended for different types of waste:

- The SFL 1-2 (500 m below ground level) intended for vitrified waste and spent fuel.

- The SFL 3 (500 m below ground level) intended for low- and medium-level reprocessing wastes.
- The SFL 4 (300 m below ground level) intended for waste from operation and decommissioning.
- The SFL 5 (300 m below ground level) intended for core components.

The waste will be surrounded by a number of barriers, including bentonite. The spent fuel in SFL 1-2 will, for example, be surrounded by its encapsulation (a copper canister), bentonite and the bedrock.

Table 5 shows estimated amounts of some nuclides in fusion blanket waste and SFL 1-2 waste 40 years after shut-down. The total activity in the SFL 1-2 waste 40 years after shut-down will be $4.2 \cdot 10^{10}$ GBq including (17):

- $7.8 \cdot 10^{9}$ GBq from heavy nuclides in spent fuel
- $3.4 \cdot 10^{10}$ GBq from fission products in spent fuel
- $8.4 \cdot 10^{7}$ GBq from induced activity in metal components of fuel
- $4.1 \cdot 10^{6}$ GBq from induced activity in fuel boxes and boron glass rod bundles.

The fusion waste figures in Table 5 should be multiplied by a factor of about 20 to give activities for a comparable level of power production. The activities of the long-lived nuclides Ni-59 and Tc-99 will then be $1 \cdot 10^{5}$ and $8 \cdot 10^{5}$ GBq respectively; i.e. still lower than the amounts of the nuclides in SFL. In addition, no heavy nuclides are present in the fusion waste.

TABLE 5. Estimated amounts of some nuclides in fusion blanket waste from a 5000 MW_{th} tokamak fusion reactor (UWMAK-I) after 10 years of operation and 40 years of decay compared to the amounts of the nuclides in SFL waste after 40 years of decay (15, 17).

Nuclide	Activity in fusion waste GBq	Activity in SFL with 6000 tonnes U GBq
Ni-59	$6 \cdot 10^3$	$8.7 \cdot 10^5$
Ni-63	$6 \cdot 10^6$	$1.0 \cdot 10^8$
Co-60	$2 \cdot 10^7$	$5.7 \cdot 10^6$
Tc-99	$4 \cdot 10^4$	$3.4 \cdot 10^6$
H-3	1)	$1.5 \cdot 10^7$
Mo-93	$9 \cdot 10^5$	-

1) Function of temperature; maximum 10^9 GBq in the first wall (4).

3.5 Sea disposal

Sea disposal of low level radioactive waste has been practised by a number of countries. In other countries, among those Sweden, sea dumping has been abandoned. There is presently only one site in operation. This site, which has an area of about $4 \cdot 10^3$ km^2 and an average depth of about 4400 m, is situated approximately 700 km from land (the coasts of Ireland and Spain) (18).

The dumping of packaged radioactive wastes is governed by the London Dumping Convention. The convention divides radioactive wastes into two categories (18):

- high-level (Annex I) wastes, which are considered unsuitable for dumping in the oceans
- other (Annex II) radioactive wastes, which may be dumped under a national permit.

The IAEA has prepared the following definition for Annex I waste (18): Radioactive waste unsuitable for dumping at sea means any waste with a specific activity exceeding

- 1 Ci/tonne for alpha-emitters (10^{-1} Ci/tonne) Ra-226 and supported Po-210)
- 10^2 Ci/tonne for beta/gamma-emitters with half-lives $\geq$ 0.5 years (excluding tritium) or beta/gamma-emitters with unknown half-lives
- 10^6 Ci/tonne for tritium and beta/gamma-emitters with half-lives < 0.5 years.

The above activity concentrations shall be averaged over a gross mass not exceeding 1000 tonnes.

The definition is based on an assumed upper limit to the mass dumping rate of 100 000 tonnes per year at a single dumping site.

In countries where sea disposal is allowed this method could be considered for low-level fusion waste (e.g. solid waste from repair operations).

3.6 Declassification

Declassification for unrestricted reuse could be of interest for fusion waste with very low activity. The activity level perhaps first has to be decreased by intermediate storage for decay or/and by detritiation.

The National Radiation Protection Institute (SSI) in Sweden has not specified any activity limits for declassification of very low level nuclear waste. A license must instead be issued for each specific lot of scrap metal based on the applicants declaration of the activity content in the lot, the method used to measure the activity, and a description of the origin of the material (21).

International working groups under the auspices of the IAEA and CEC are at present working on relevant activity limits for declassification (4).

4 DISPOSAL STRATEGY

4.1 The Swedish planning for LWR wastes

Figure 1 shows a basic flow chart over the handling of radioactive residues from the nuclear power plants in Sweden. The treatment and storage of the waste are primarily determined by its content of activity and decay times. At the nuclear power plants, the low- and medium-level wastes from reactor operation are treated in various ways (solidified into bitumen and concrete) in order to facilitate safe transportation and storage. The spent fuel is presently stored on a temporary basis in water pools at the power plants for subsequent removal to the central intermediate storage facility CLAB, which is under construction, or for transportation abroad for reprocessing. The reprocessing waste is returned to Sweden for disposal (19).

Responsibility for management of the waste produced at the nuclear power plants will rest with the nuclear power utilities, who will also have primary responsibility for ensuring that funds are available for this activity. This is stipulated in the law concerning the financing of future expenses for the handling and disposal of spent nuclear fuel etc., the "Financing Act" (1981:669), which came into force on July 1, 1981. The law and regulations based on it provide that (19):

- funds shall be allocated during the operational lifetime of the nuclear power plants to cover the costs of providing a safe system for the handling and storage of nuclear residues, and these funds shall be administered by the Government through a special committee. The funds shall also cover the cost of decommissioning (including dismantling)

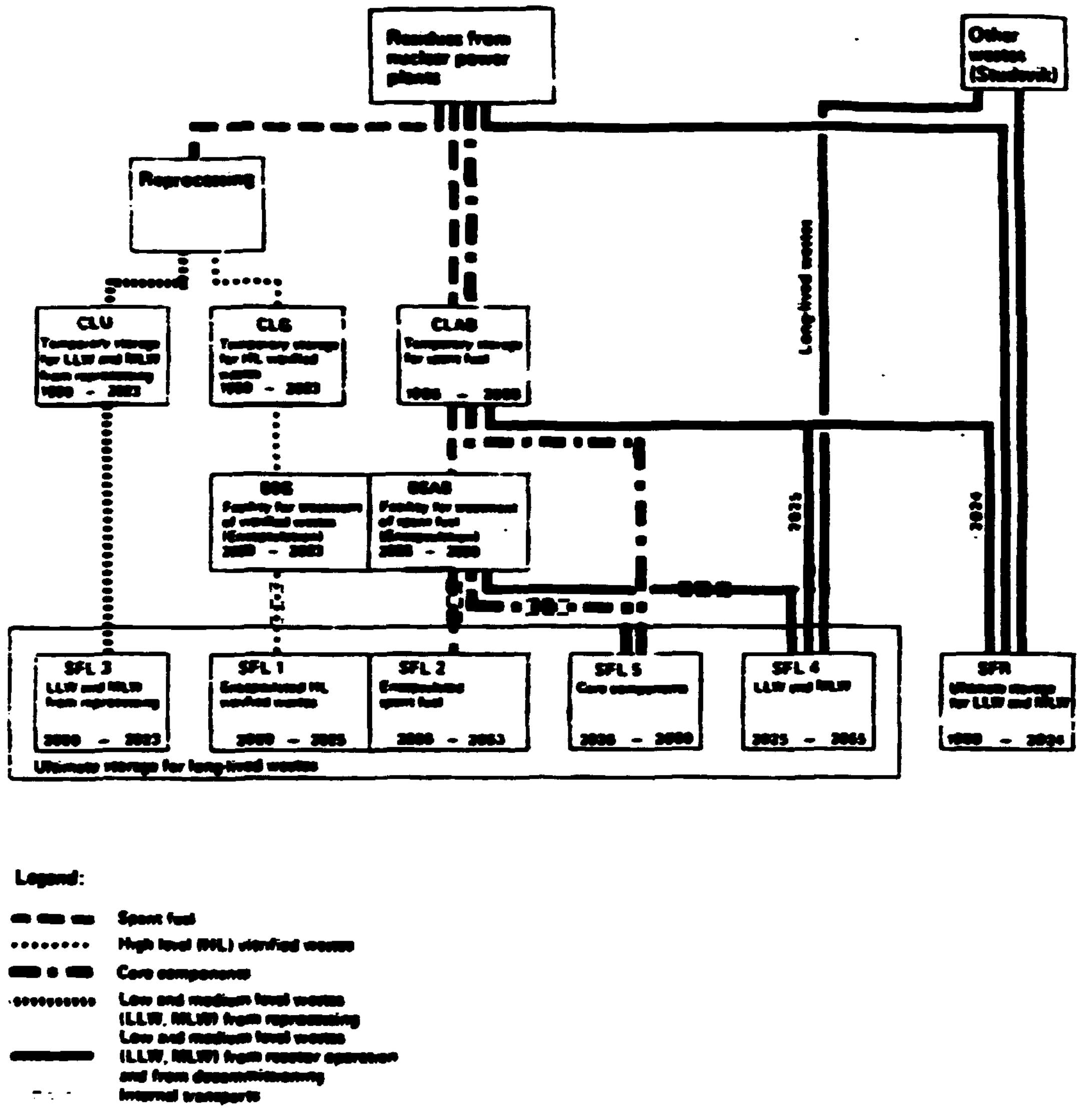


FIGURE 1 Facilities and handling sequence for residual products from nuclear power generation in Sweden (19)

the power plants, but not the handling and storage of the low- and medium-level wastes (operating waste) which are generated continuously during the operation of the power plants.

- the size of the fee shall be determined annually by the Government on the basis of current government plans and be charged in relation to the quantity of energy generated by each reactor.

- the owner of the reactor shall submit to the National Board for Spent Nuclear Fuel, NAK, by the end of June of each year at the latest, plans for future research and development work and for the construction and operation of the facilities required for the handling and storage of spent nuclear fuel, or radioactive waste originating from it, and for the decommissioning (including dismantling) of the reactor plant. (The Swedish nuclear power companies have commissioned the Swedish Nuclear Fuel Supply Company, SKBF, which is owned jointly by the power companies, to carry out this work on their behalf.) <u>Note</u>

The strategy for the treatment and disposal of radioactive wastes from internal and external sources at STUDSVIK is presented in Figure 2. In this figure the centralized repositories SFR and SFL, the intermediate storage facility of the AMOS project at STUDSVIK, and on-site shallow land burial facilities at nuclear sites are indicated.

<u>Note</u> By the 1 July 1984, SKB, Swedish Nuclear Fuel and Waste Management Company.

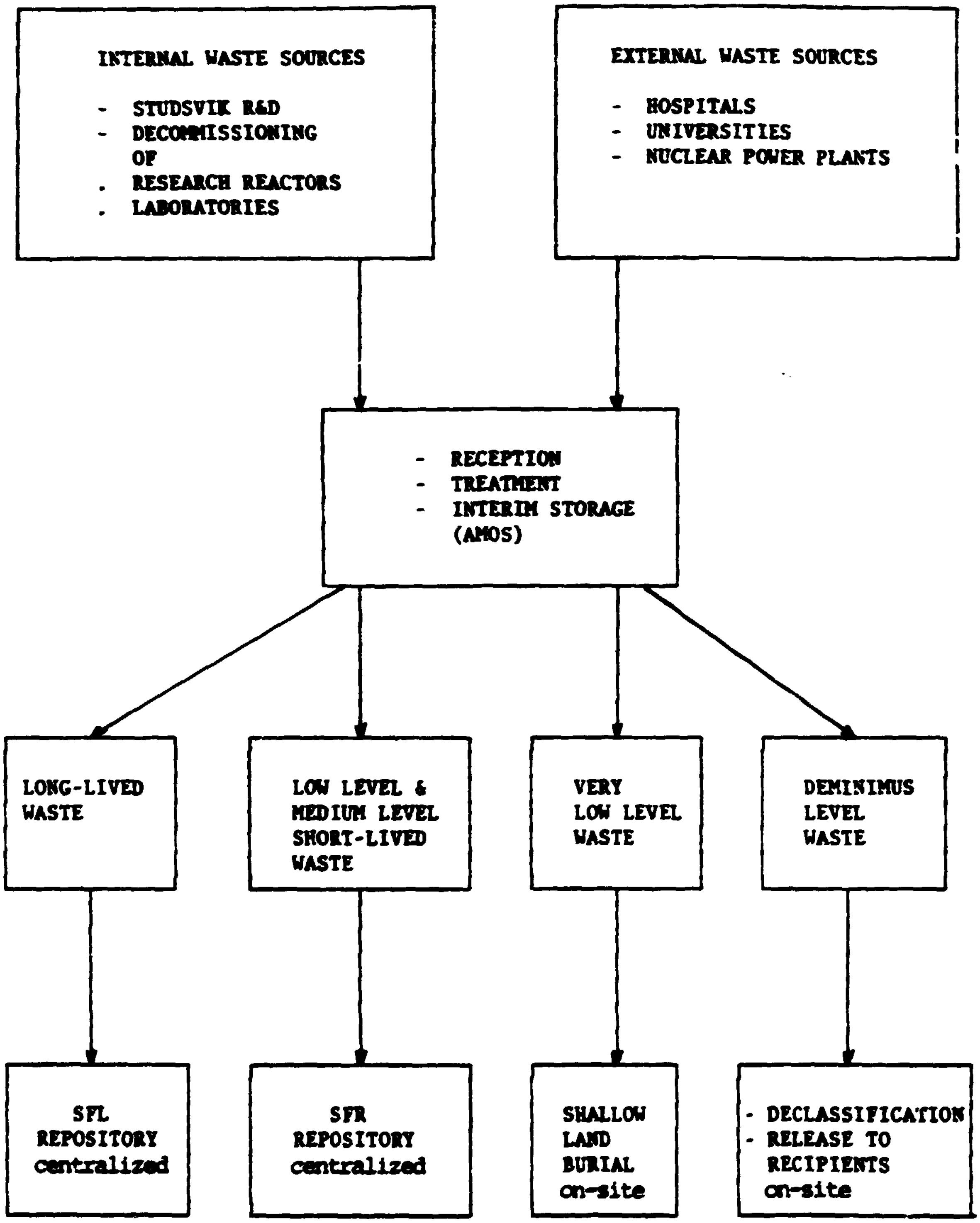


FIGURE 2 Sources and disposal strategy for radioactive wastes at Studsvik.

4.2 Application to fusion wastes

Figure 3 schematically illustrates a tentative strategy for the handling and disposal of fusion waste based on the present Swedish disposal strategy for fission and non-nuclear radioactive wastes.

After an intermediate storage for the very short lived nuclides to decay, some of the waste components should be treated by degassing for recovery or removal of tritium. In the figure the tritium limits have been taken as proposed by Rouyer et al (7). The limits given for specific beta-gamma activity are very approximate, as Swedish licensing authorities have not established fixed limits for specific activities.

Provided intermediate storage and tritium removal are applied it seems feasible to dispose of fusion waste of different categories by using the various types of repository in the Swedish strategy, or equivalent options in other countries.

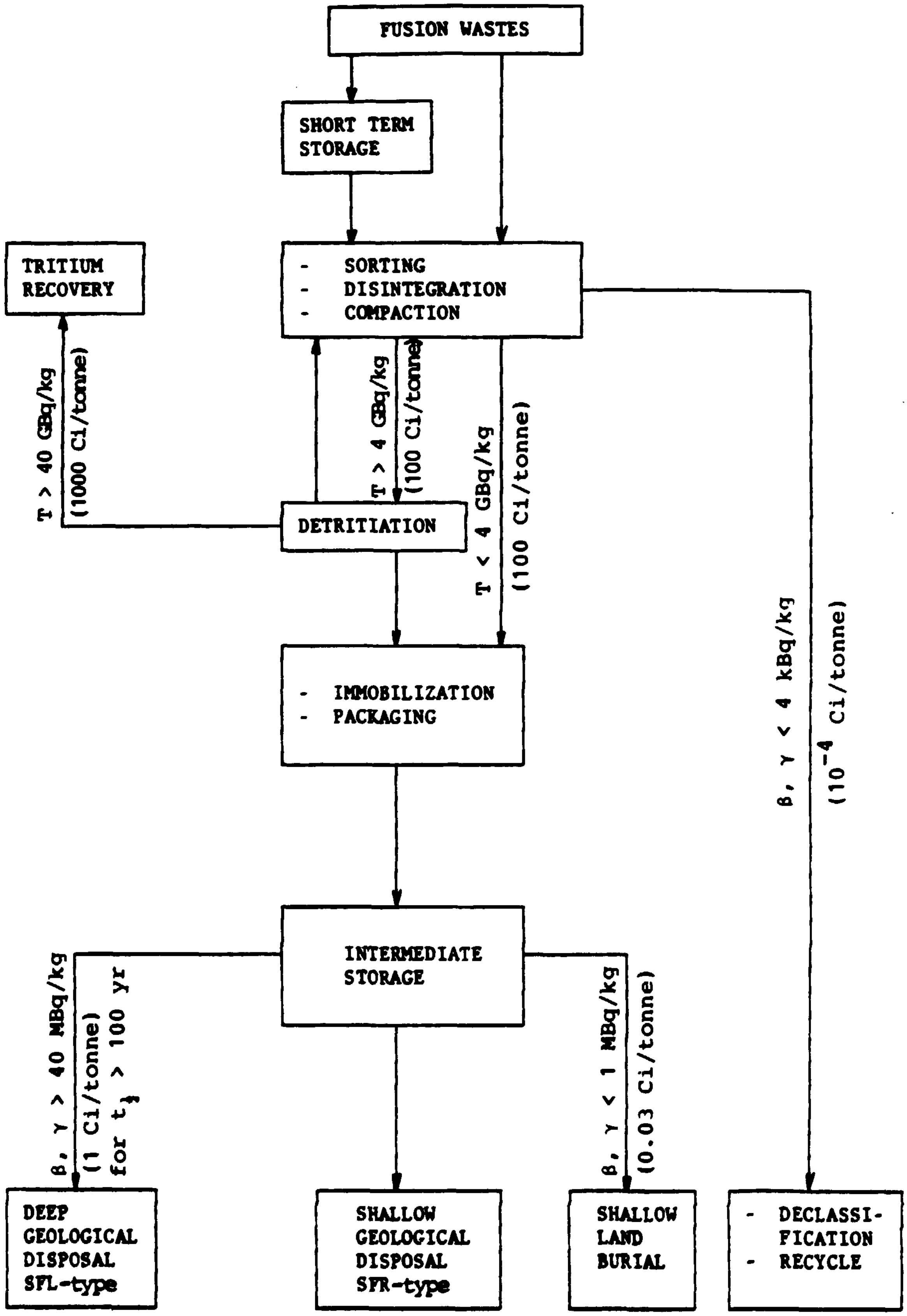


FIGURE 3 Tentative strategy for fusion wastes.

5 CONTINUED PROGRAMME

5.1 Considerations

A Governmental investigation has recently presented its conclusions and recommendations for continued fusion research in Sweden and continued participation by Sweden in the fusion research programme of the European Community (9). The outcome of this investigation and subsequent Government actions and proposals will hopefully make possible the continuation and expansion of the waste programme, according to planning.

The efforts on waste management during 1985 will, besides continued work on disposal strategy, include experimental work on the migration and sorption of fusion waste nuclides where relevant data are lacking or insufficient. Exchange of information with Saclay and other centra is here of great value and will continue.

5.2 Experimental work

As input to safety analyses of storage and disposal of fusion waste it is important to have knowledge about migration and sorption in geologic systems for the various radioactive nuclides in the fusion waste. A lot of migration and sorption experiments in Sweden and other countries have been performed for high level, medium level, and low level waste from fission reactor operation. From these experiments also information of interest for fusion waste storage and disposal may be found.

A literature survey will start during the first part of 1985.

The results found in the literature have to be completed by migration and sorption laboratory experiments for systems where data are insufficient or missing.

The laboratory experiments will start during 1985 probably with Mo-99 as tracer in systems imitating Mo-93 in a geological repository.

5.3 Safety analysis

The literature data and the results of the laboratory experiments will be used as the input information to a safety analysis of storage and disposal of fusion waste.

The safety analysis will start at the end of 1985 or beginning of 1986.

6 CONCLUDING REMARK

The work on nuclear waste management has in Sweden advanced to complete concepts near realization and to integrated planning for the tail end of the LWR nuclear fuel cycle. These experiences form a natural basis for an approach to the management of fusion wastes as well. This report has used the relevant documentation available in Sweden for this application.

It is a great pleasure to acknowledge the advice from and cooperation with other people working in the S&E part of the CEC fusion programme, particularly Mr J-L Rouyer and his coworkers at IPSN, CEN-Saclay.

REFERENCES

1. FARFALETTI-CASALI F et al
The NET System Integration
Presented at the 13th Symposium on Fusion Technology in Varese, Italy, September 24-28, 1984

2. HARRIES D R, DUPOUY J-M
Materials Selection for NET and Associated R&D Programmes
Presented at the 13th Symposium on Fusion Technology in Varese, Italy, September 24-28, 1984

3. CHEVEREAU G
Adaption to NET of a Beryllium Canister Blanket Concept
Presented at the 13th Symposium on Fusion Technology in Varese, Italy, September 24-28, 1984

4. ROUYER J L
CEA-IPSN comments
October 22, 1984

5. ICRP
Limits for Intakes of Radionuclides by Workers
ICRP Publication 30, Part 1
Annals of the ICRP, 2, 1979

6. HÄFELE W
Fusion and Fast Breeder Reactors
IIASA, RR-77-8 (1976)

7. ROUYER J L, GIROUX M
Fusion Tritiated Waste Management Strategy
Personal communication, June, 1984

8. GORE B F, KASER J D, KABELE T J
Fusion Fuel Cycle Solid Radioactive Wastes
PNL-2719, UC-20c, (1978)

9. KASER J D, POSTMA A K and BRADLEY D J
Management of Non-tritium Radioactive Wastes from Fusion Power Plants
BNWL-2019, 1976

10. FORSSTRÖM H
Management of Radioactive Waste at Swedish Nuclear Power Plants
Presented at Seminar on the Management of Radioactive Waste from Nuclear Power Plants, Karlsruhe, 5-9 October 1981
IAEA-SR-57/18

11. Swedish Code of Statutes 1984:14
Act on nuclear activities (in Swedish)
31 January 1984

12. OFFICE OF THE FEDERAL REGISTER
Code of Federal Regulations 10, Energy
Part 61, Licensing Requirements for
Land Disposal of Radioactive Waste
(CFR 10/61)
Revised as of January 1, 1983

13. ABDOU M et al
Safety and Environmental Impact
INTOR
Phase 1, Volume 3, 1981 (prel)

14. SKBF/KBS
Radioactive waste management plan
Plan 82
Part 2 Facilities and costs
Technical report 82-09:2, 1982

15. STENQUIST C
Radioactive elements in a fusion reactor of
Tokamak type (in Swedish)
Studsvik Technical Report NW-81/63, 1981

16. SKBF/KBS
SFR repository for reactor waste
Prel Safety Report (in Swedish)
March 1982

17. SKBF/KBS
Final Storage of Spent Nuclear Fuel, KBS-3
I General, 1983

18. TEMPLETON W L, PRESTON A
Ocean Disposal of Radioactive Wastes.
Radioactive Waste Management and the
Nuclear Fuel Cycle
Volume 3(1), page 75-117, 1982

19. SKBF/KBS
Radioactive waste management plan
Plan 82
Part 1, General
Technical report 82-09:1, 1982

20. GUETAT, Ph, CEA/IPSN
Personal communication, 84-10-22

21. BRODEN, K, HULTGREN, A, AND OLSSON, G
Storage and Disposal Facilities for Spent
Fuel and Radioactive Waste in Sweden
STUDSVIK Technical Note NW-85/893, 85-02-01

STUDSVIK/NW - 84/830

THE HANDLING AND DISPOSAL OF FUSION WASTES

Progress report February 1985

Karin Brodén
Åke Hultgren
Gunnar Olsson

Studsvik

Studsvik Energiteknik AB S-611 82 NYKÖPING
SWEDEN Telefon 0155-800 00 Telex 64013 studss