Low Activation Tokamak Reactors

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LOW ACTIVATION TOKAMAK REACTORS

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SUMMARY

In order to realize the full potential of fusion as an environmentally benign source of energy, it is necessary to avoid the difficulties of disposing of high-level waste by deep geological burial. Because of the large fluxes of high energy neutrons in a typical fusion design, activation of structural materials can result in highly radioactive components which may not satisfy low-level waste disposal criteria.

Extrapolating the current physics data base and adapting blanket designs that are being developed in the US, Europe, and Japan based on advanced materials, a set of demonstration reactor designs were developed which satisfy common physics and engineering constraints. Because of different material properties, the dimensions of the reactors varied, when constrained to meet the same engineering and physics limits.

For each design, calculations of various waste disposal parameters were performed. The reactors were modeled neutronically using the one-dimensional discrete ordinates transport code, ONEDANT with S_8 quadrature and the MATXS10 cross section library, which contains 30 neutron and 12 photon groups with P_4 scattering. The neutron activation calculations were performed with the REAC*3 code and the associated cross sections which were specifically developed for high energy fusion neutron activation calculations. The

Microshield code was used to calculate contact dose rates based on the REAC*3 photon emission rates.

For each design, the specific activity, total activity, life cycle waste volume, contact dose rate and a waste disposal rating based on detailed isotope specific near-surface burial limits were evaluated for comparison with representative low-level waste criteria that might be expected for fusion wastes.

Some designs will satisfy near-surface burial criteria, while others would undoubtedly be classified as high-level waste. Existing austenitic stainless steels clearly would not satisfy low-level waste criteria. Of the advanced materials under development, vanadium alloys seem the most promising for satisfying low-level waste disposal criteria, although ferritic steel alloys might also qualify as low-level waste. Silicon carbide appears to be marginal in this respect. The martensitic steel (MANET) and the manganese steel VA64 considered in this evaluation clearly would not satisfy low-level waste criteria, but both of these materials are understood to have low-activation versions that are being considered and possibly under development.

CHAPTER I

INTRODUCTION

The future of fusion as a source of power relies on its scientific and technical feasibility and its social acceptability. The development of experimental and demonstration facilities is currently underway to evaluate the scientific and technical feasibility of fusion power. In order to realize the full potential of fusion as an environmentally benign source of energy, and hence to achieve acceptability, it is desirable, probably necessary, to avoid the difficulties of disposing of high-level waste (HLW) by deep repository burial, thus avoiding the problems currently faced by fission reactors. Because of the large fluxes of high energy neutrons in a typical fusion design, activation of structural materials can result in highly activated components which may not satisfy low-level waste (LLW) disposal criteria. This could be an important issue for the societal acceptability of fusion power.

There are a variety of materials being considered for fusion reactor designs. However, these generally have been designed without regard to LLW or other key disposal criteria. At present, it is unclear if it is possible to design a reactor that will completely satisfy the LLW criteria. In fact, the LLW criteria that will be applied to fusion are themselves uncertain.

This analysis looked at a number of possible demonstration reactor (DEMO) designs based on common physics assumptions, but different structural and breeding materials and coolants. The designs were evaluated to determine if these materials would satisfy LLW disposal criteria. A number of activation parameters were evaluated, including, waste disposal rating, specific activity, total activity, volume, and contact dose.

Reactor designs were developed for several possible tokamak demonstration reactors, all based on the intermediate/advanced physics design basis (29), which could be established by the operation of the International Thermonuclear Experimental Reactor (ITER) (1). Four reference designs were based on the different blanket designs which are being developed in Europe, Japan, and the USA for the DEMOs. A Japanese, water-cooled, solid breeder, ferritic steel structure design (2) was chosen. The European, water-cooled, lithium lead breeder, MANET (Martensite for NET) structure design (3) was a second device. The final two reference designs chosen were based on U.S. blanket designs. The first was a lithium-cooled, vanadium alloy structure design being studied by Argonne National Laboratory (4). The second was a helium-cooled, solid breeder, silicon carbide structure design which was studied in the ARIES-I project (5) . A number of variants on one of these reference designs was also considered.

All reactors were designed to operate at the same fusion power level (1500 MW) and the same design lifetime (10 EFPY) so that results will be directly comparable. The physical dimensions of the different designs were determined to satisfy a common set of physics and engineering design constaints (6). Common physics parameters and the thermo-mechanical properties of the structural materials and coolants were used for all designs. The reactors were designed to assure that stress limits, radiation damage limits, and other parameters were not exceeded and that a stable, confined plasma can be maintained at the specified power level. This results in designs that were quite dissimilar in size because of the widely different thermo-mechanical properties of the different materials. The resulting reference designs are intended to be representative of designs of demonstration reactors at the specified power and, therefore, properly characterize the waste streams that would result and allow for direct comparison between the different designs.

CHAPTER II

COMPUTATIONAL PROCEDURE & COMPUTER CODES

In order to model the reactor and perform the desired calculations four separate codes were required. These codes perform the neutronics calculations, the fusion reactor design parameter determination, the activation calculations, and the dose calculations.

The neutronics code used was the ONEDANT code (7) This is a one dimensional discrete ordinates transport code. An S_8 angular quadrature was used. The cross section library used was MATXS10 (8,9), which was developed specifically for high-energy neutron transport calculations. The cross sections set is a P_4 scattering set and consists of 30 neutron groups and 12 photon groups.

Fusion reactor design parameters were calculated using a code which determines the dimensions of the various reactor components so that the reactor will be able to maintain a stable, confined plasma and meet the various engineering constraints (6). This code used as input the reactor power level, plasma physics parameters, and material properties. Plasma physics parameters corresponding to the *intermediate advanced tokamak mode* (10) were used. The code determined the stresses at key locations and assured that the ASME code standard were met (<1/3 Ultimate Strength and <2/3 Yield Strength). The minimum thickness of the various components was determined from stress, heat removal, tritium breeding, and radiation shielding constraints. The calculated dimensions were used in the neutronics calculation. Radiation damage lifetimes were also computed using displacement cross sections from MATXS10 and neutron fluxes calculated with ONEDANT.

The neutron activation analysis was performed using the REAC*3 code (11). This code and its associated activation cross sections were developed specifically for high energy neutron activation analysis in the fusion environment. It includes an extensive 175 energy group activation cross section library. The 30 group neutron flux from ONEDANT was lethargy interpolated to form the 175 group fluxes. This code was then used to calculate the radioactive inventories for specified times and operational scenario.

The Microshield code (12) was used to perform the contact dose rate calculations. One parameter of interest in this work is the contact dose rate of a uniformly contaminated semi-infinite slab. The REAC*3 code outputs the decay photon emission rate by energy group and the Microshield code was used to determine a semi-infinite slab contact dose rate response function for each of the decay photon energy groups and material. The response function was then folded with the REAC*3 output to determine the contact dose.

Figure II.1 shows a schematic of the process used in this analysis. The figure shows the interrelationship between the various codes and results derived from each. The parameters are defined in chapter V.

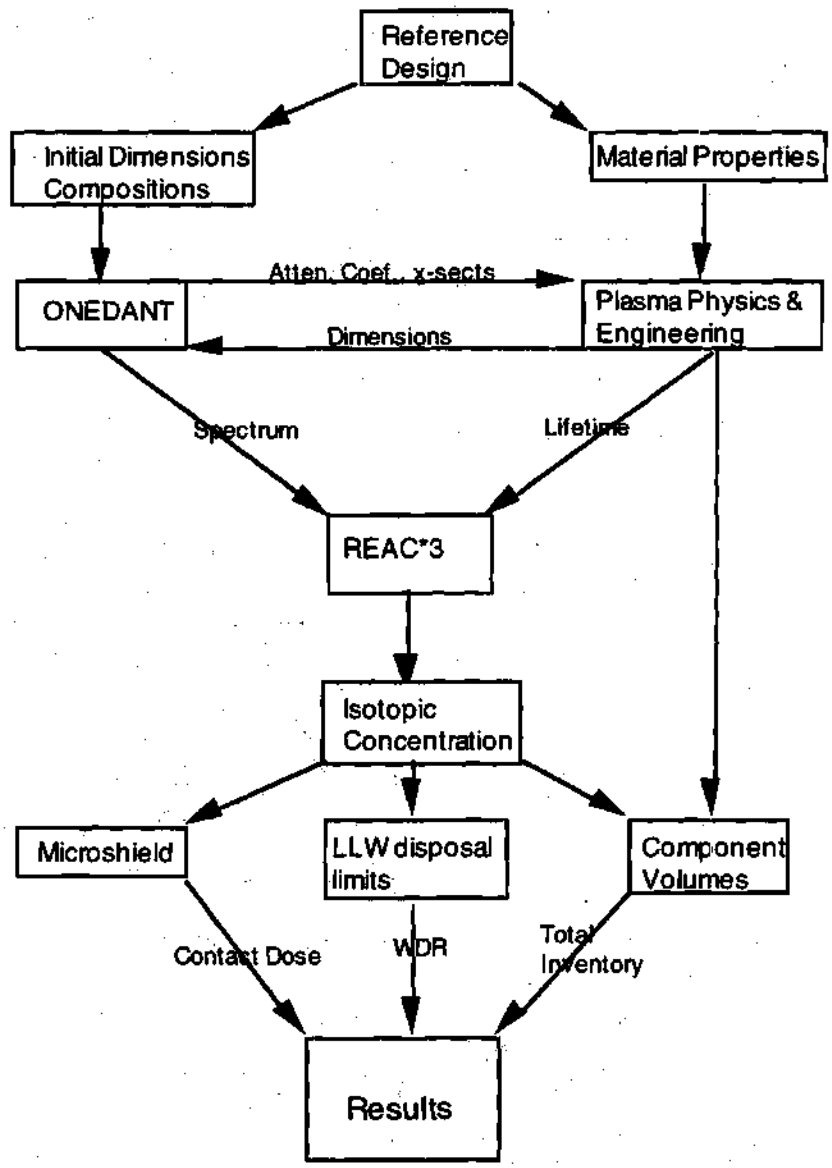

Figure II.1

Analysis Schematic

CHAPTER III

REFERENCE BLANKET DESIGNS

The principal blanket design options being developed for the DEMO in the United States, Japan, and Europe were chosen as the basis for the references designs. These reference designs were based on a ferritic steel/water/lithium oxide/beryllium blanket design, a martensitic steel/water/lithium lead blanket design, a vanadium/lithium blanket design, and a silicon carbide/helium/ lithium zirconate/beryllium blanket design. In addition, several variants of the water/lithium oxide/beryllium blanket design with different structural materials were considered. The materials and designations used for each design are given in table III.1. Table III.2 includes some of the basic parameters used for the original designs. All material properties are given in chapter IV.

III.A. Reference FeS/Li_2O/H_2O Blanket Design (R1)

Mori et al. (2) discussed a blanket design for a steady state tokamak reactor. Their design is water-cooled and uses a solid lithium oxide (Li_2O) breeder, and beryllium (Be) neutron multiplier. The first wall is a tube bank with ferritic steel (FeS) structure and cooled with pressurized water (H_2O). Behind the first wall is a replaceable breeding blanket which consists of solid Li_2O pebbles, a Be multiplying region and intermittent cooling tubes. Behind the replaceable blanket is a permanent breeding blanket intended to last the life of the plant. The details of the blanket design are shown in figure III.1.

III.B. Reference MS/$Li_{17}Pb_{83}$/H_2O Blanket Design (R2)

Giancarli et al. (3) have developed a design for the Next European Torus (NET). The first wall design consists of a pressurized water tube bank. The structural material is a martensitic steel (MS) and referred to as Martensite for NET (MANET). The blanket is constructed of the same structural material, liquid lithium lead ($Li_{17}Pb_{83}$) breeder, and pressurized water coolant in MANET tubes for coolant. The $Li_{17}Pb_{83}$ is circulated slowly to extract the tritium. The details of the blanket design are shown in figure III.2.

III.C. Reference V/Li Blanket Design (R3)

Ehst et al. (4) have developed a liquid lithium-cooled design using a vanadium (V) alloy for the structural material. The first wall is a slab of this alloy with lithium (Li) coolant flowing behind it. The blanket consists of lithium flowing through coolant channels defined by the vanadium structure. Behind the blanket, there is a neutron reflector which consists of calcium oxide (CaO), lithium coolant, and vanadium structure. The details of the blanket design are shown in figure III.3.

III.D. Reference SiC/Li_2ZrO_3/He Blanket Design (R4)

AIRIES project developed a design AIRIES-I (5) using silicon carbide (SiC) structure and helium (He) coolant. The breeding material is solid lithium zirconate (Li_2ZrO_3), with isotopically tailored Zr to reduce off-site exposure during an accident. This design incorporates a Be neutron multiplier to achieve sufficient tritium breeding ratio (TBR). The details of the blanket design are shown in figure III.4.

III.E. Blanket Design Variants

In order to obtain a more direct comparison of different possible structural materials, variants of the FeS/Li_2O/H_2O blanket design R1 described in section III.A with other structural materials, were considered. The materials studied were stainless steel 316 (316SS), the manganese steel alloy VA64, the proposed improved stainless steel known as PCA, and the vanadium alloy V-4Cr-4Ti. The first three are all austenitic steels and may be used in experimental, and early fusion reactor designs, because of a better understanding of their properties.

Table III.1

Blanket Design Identification

	Design	Structure[1]	Coolant	Breeder	Multiplier
R1 (2)	FeS/ Li_2O/H_2O	Ferritic Steel	H_2O	Li_2O	Be
R2 (3)	MS/$Li_{17}Pb_{83}$/ H_2O	MANET	H_2O	$Li_{17}Pb_{83}$	Pb
R2 (4)	V/Li	V-4Cr-4Ti[2]	Lithium	Lithium	none
R3 (5)	SiC/Li_2ZrO_3/ He	Silicon Carbide[2]	Helium	Li_2ZrO_3	Be
V1	V/ Li_2O/H_2O	V-4Cr-4Ti[2]	H_2O	Li_2O	Be
V2	316SS/ Li_2O/H_2O	316SS	H_2O	Li_2O	Be
V3	PCA/ Li_2O/H_2O	PCA	H_2O	Li_2O	Be
V4	VA64/ Li_2O/H_2O	VA64	H_2O	Li_2O	Be

1. Dispersion strengthened copper is the structural material for the divertor plate in all designs.
2. Structural material in the vacuum vessel and shield is the ferritic steel.

Table III.2

Design Parameters for Original Blanket Designs

	FeS/ Li_2O/H_2O	MS/$Li_{17}Pb_{83}$/ H_2O	V/Li	SiC/Li_2ZrO_3/ He
Major Radius		6.3 m	6.0 m	6.75 m
Minor Radius		1.82 m	1.0 m	1.60 m
Fusion Power	3000 MW	2200 MW	1950 MW	1925 MW
Average First Wall Load	3.0 MW/m^2	2.2 MW/m^2	5.0 MW/m^2	3.1 MW/m^2
Peak First Wall Load	5.0 MW/m^2			4.0 MW/m^2
Reference	2	3	4	5

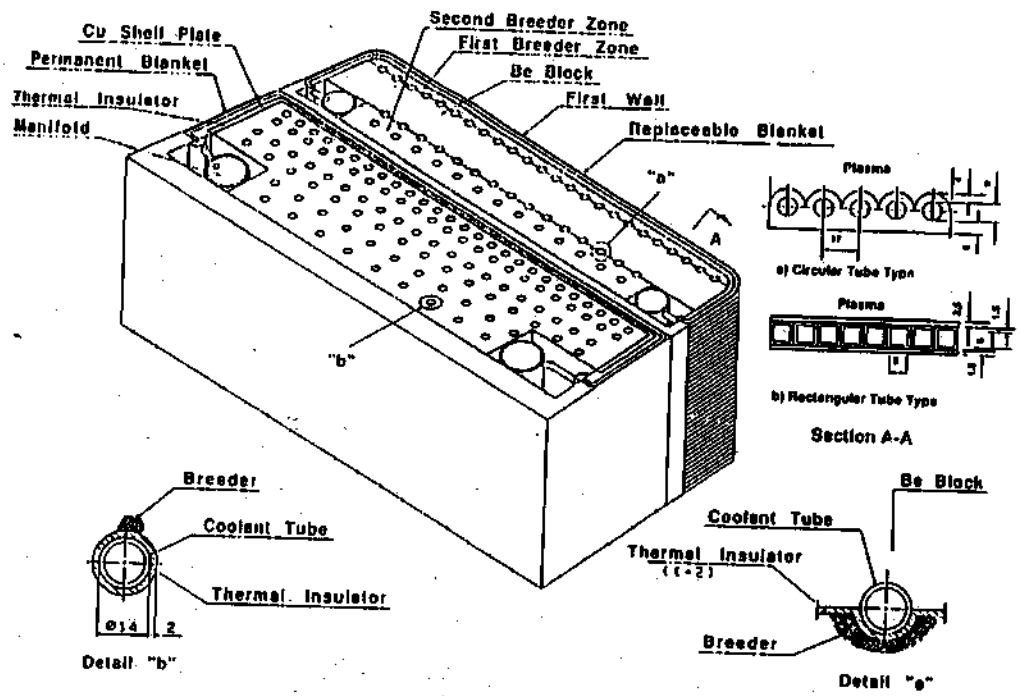

Figure III.1

Japanese $FeS/Li_2O/H_2O$ Blanket Design (2)

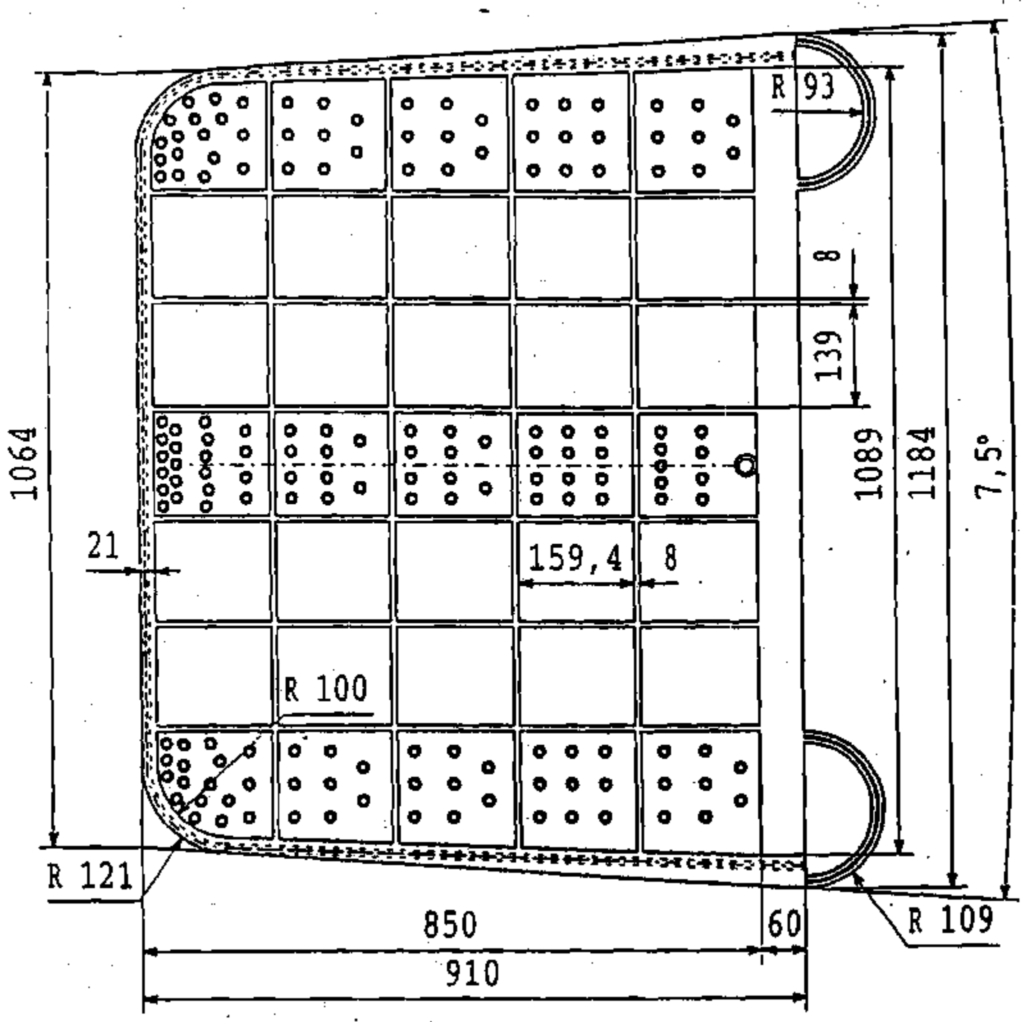

Figure III.2

European MS/$Li_{17}Pb_{83}$/H_2O Blanket Design (3)

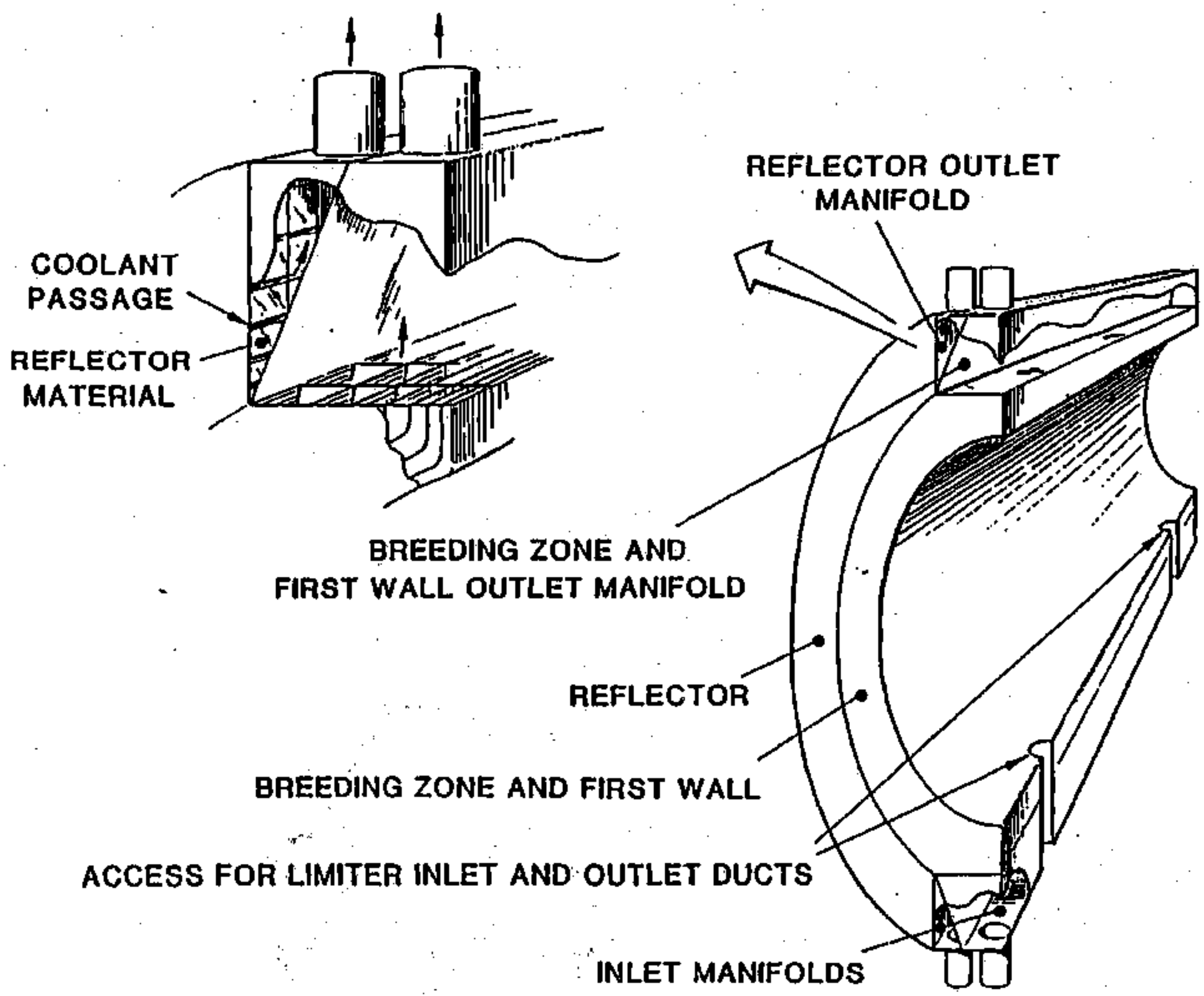

Figure III.3

Argonne National Laboratory V/Li Blanket Design (4)

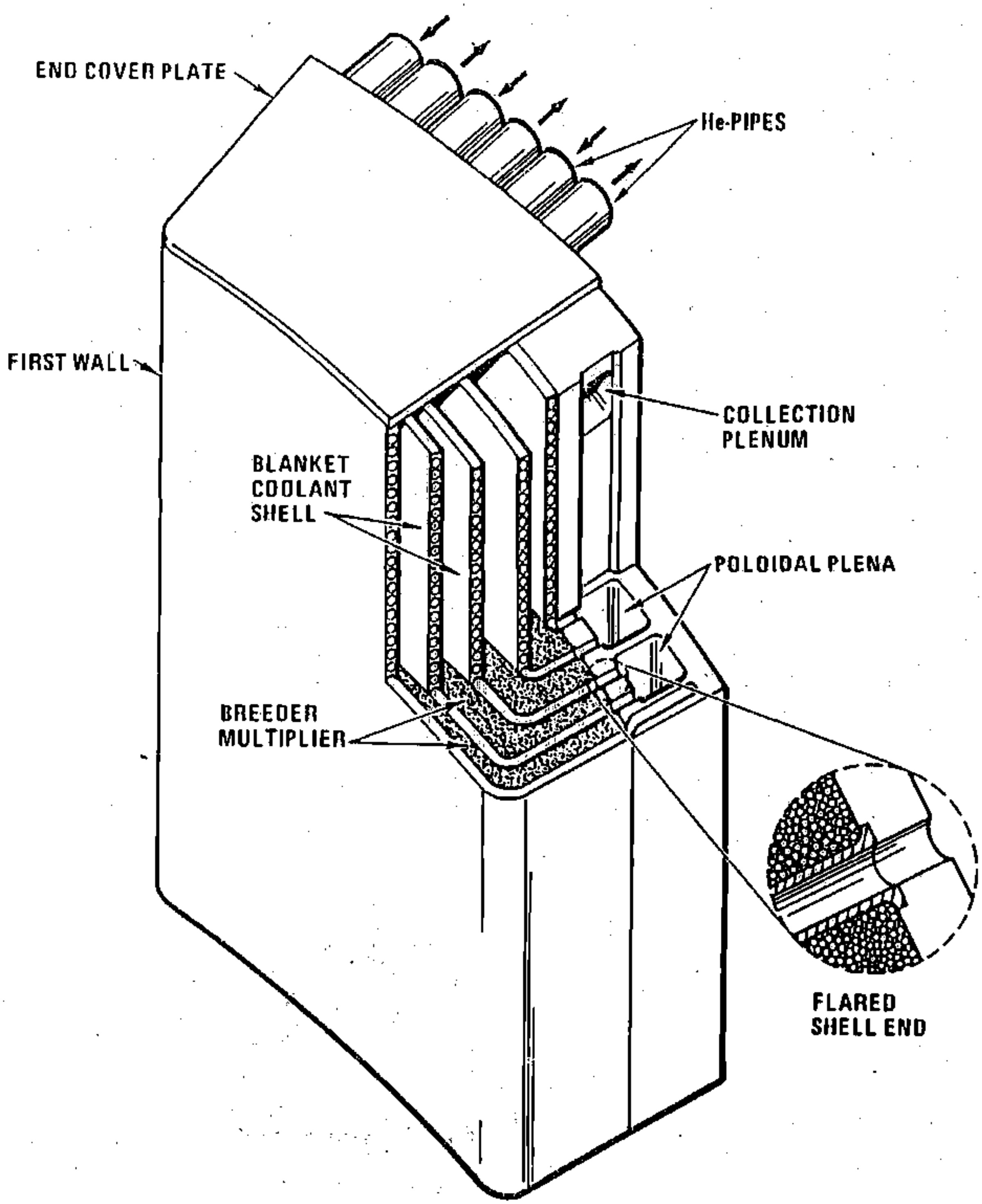

Figure III.4
AIRIES-I $SiC/Li_2ZrO_3/He$ Blanket Design (5)

CHAPTER IV

MATERIALS PROPERTIES

This chapter describes all material compositions and thermo-mechanical and radiation damage properties that were used in this research. It also gives brief discussions of why some choices were made. Thermo-mechanical properties are given in table IV.1 and compositions in table IV.2. In a fusion reactor, activation will be a primary concern. Materials must be chosen, and impurities controlled, to reduce activation. For this reason the results for the structural materials are given for both the pure (as designed) materials, and with representative level of unintentional impurities. This will show the lowest possible activation rates and the effects of the specified impurities. The impurities used are also included in table IV.2.

IV.A. Structural Materials

Reduced Activation Ferritic Steel

Low alloy steels are considered as possible low activation materials and are being actively developed in the US, Japan, and Europe. The reference structural material in the Japanese design (2) is of this type. The material properties were taken from the Nuclear Systems Materials Handbook (13) for the material HT-9m. According to Klueh (14), good agreement in materials properties exists between this material and the reduced activation steels. Gelles

(15) reports on irradiation damage of ferritic steels that they are damage resistant to 200 displacements per atom (dpa). In the Japanese design, the operating temperature is less than 500 C. The composition was taken from Bloom (16).

MANET

Martensite for NET (MANET) is the reference material in the design of the European lithium-lead blanket design (3). All properties and the composition were taken from the NET database (17). In the absence of data, a radiation damage lifetime of 200 dpa was chosen to facilitate comparison with the reduced activation ferritic. The operating temperature in this design was 500 C (3).

V-4Cr-4Ti

This material is currently under development in the US as a low-activation structural material. The properties for this material were gathered through personal communications (18). A damage lifetime of 200 dpa is used, which is expected to be a reasonable value (18). Table IV.2 contains the alloy composition (19). Since the primary motivation for development of this alloy is low activation, it is expected that impurities will be maintained at low levels and an impurity level of 1 ppm Nb was assumed (18).

Silicon Carbide

The properties of silicon carbide were taken from the AIRIES-I report (5). The mechanical properties were given in this report, which indicated that silicon carbide can operate at over 1000 C. In this report, a radiation lifetime of 200 dpa was used, and this same value was used in the present work. Impurity concentrations, which were used in this analysis, were given in the AIRIES-I report. Fetter (20) gave a different set of impurities, both are included in table IV.2.

316 Stainless Steel

This material has been used extensively in industry and a large database of its properties exists. This material exhibits high swelling rates at high temperatures and is therefore limited to operation below 400 C. Radiation damage will limit operation, with an expected lifetime of about 60 dpa (18). The mechanical properties and composition were taken from the ITER-CDA materials database (21).

PCA

This material is a modified stainless steel to improve radiation damage resistance. Properties of this material were not available. The 316SS properties were assumed. The composition was taken from Kinzig (22). In the absence of data and since PCA is designed specifically to improve radiation damage resistance, an irradiation lifetime of 100 dpa was assumed to show the effect of increased lifetime.

VA64

VA64 is a manganese stabilized austenitic stainless steel which is an alternative to 316 stainless steel. Zucchetti and Zublena (23) and Piatti and Schiller (24) studied the properties of several manganese steels. Piatti and Schiller found that VA64 had a "noticeably high thermal stress resistance" and this was the reason for selecting VA64. Piatti and Schiller found that swelling behavior of high manganese austenitic steels are similar to type 316SS. Thus, the same value of 60 dpa, as for 316SS, was used for the radiation damage lifetime . The stress limit was taken from Piatti and Schiller and all other properties were taken from Zucchetti and Zublena.

IV.B. Breeding Materials

Each of the reference designs used a different breeding material to produce the required tritium. The compositions are given in table IV.3.

Lithium Oxide

The Japanese reference blanket design (2) uses solid Li_2O for tritium breeding. The solid breeder is in pebble form at 85% theoretical density and a 70% packing factor. The Li-6 is present at 7.5% in naturally occurring lithium (25). Impurity concentrations were taken from Holdren (26).

Lithium Lead

The European reference blanket design (3) uses the eutectic $Li_{17}Pb_{83}$ liquid metal. The lithium is enriched to 90% Li-6 (3). Impurity concentrations were given by Holdren (26) and by Fetter (20). There is a large discrepancy between them. Both are given in table IV.3. The impurity concentrations from Holdren were used since this is the more recent work and Fetter was cited in the Holdren paper.

Lithium

The Argonne reference blanket design (4) uses pure lithium in liquid metal form as both the breeder and coolant. The lithium is not enriched. The impurity concentrations were taken from Fetter (20).

Lithium Zirconate

The AIRIES-I reference blanket design (5) uses solid Li_2ZrO_3 for tritium breeding. The solid breeder is in pebble form at 90% theoretical density with an 80% packing factor. To reduce activation, the zirconium is isotopically tailored. The tailored composition (5) is 99.908% Zr-92; 0.057% Zr-90; 0.013% Zr-91; 0.019% Zr-94; 0.003% Zr-96. The Li-6 was enriched to 80%. The impurity concentrations were also taken from this report.

IV.C. Neutron Multipliers

In the Japanese reference (2) design and the AIRIES-I reference design (5), beryllium (Be) was added as neutron multiplier to increase the tritium breeding ratio (TBR). In the Japanese design, the beryllium is present in solid blocks. In the AIRIES-I design, it is present in pebble form at 90% theoretical density and a 80% packing factor. The impurity concentrations were taken from Fetter (20). The composition of beryllium is included in table IV.4.

IV.D. Divertor Material - Dispersion Strengthened Copper

The divertor will be subject to extremely high heat loads and one of the leading candidate materials is the dispersion strengthened copper, which is being developed for ITER (21). Copper has very high thermal conductivity and by dispersion strengthening with alumina (Al_2O_3), it is expected to be able to withstand this intense loading. The properties were taken from the ITER-CDA materials database (21). The radiation damage lifetime of 150 dpa was chosen based on the report by Zinkle and Fabritsiev (27). In this report, they found that swelling was still minimal at values up to 150 dpa. An operation temperature of

500 C was chosen based on Zinkle and Fabritsiev, in which they found that "based on the available data, dispersion strengthened copper ($Cu-Al_2O_3$) may be used up to temperatures in excess of 500 C". The impurity concentrations for copper were taken from Holdren (26). The composition is included with the structural materials in table IV.2.

Table IV.1

Structural Material Properties

	HT-9m (13,14,15)	MANET (17)	V-4CrTi (18)	SiC (5)	316SS (18,21)	VA64 (23,24)	DS copper (21,27)
US(Pa)	3.96E+08	4.94E+08	4.40E+08		4.85E+08		2.50E+08
YS(Pa)	3.07E+08	4.26E+08	2.70E+08		1.65E+08		2.20E+08
Stress Limit (Pa)	1.02E+08	1.42E+08	9.00E+07	1.40E+08	5.50E+07	2.70E+08	8.33E+07
Expansion Coeff. (1/K)	1.23E-05	1.22E-05	1.04E-05	4.40E-06	1.80E-05	1.64E-05	1.85E-05
Elongation Modulus (Pa)	1.81E+11	1.81E+11	1.12E+11	3.64E+11	1.66E+11	1.67E+11	9.93E+10
Thermal Conductivity (W/m-K)	30.0	26.2	34.0	15.0	14.8	25.2	288.3
Poisson's ratio	0.30	0.30	0.37	0.16	0.27	0.283	0.33
Temp (C)	500	500	600	1000	400	500	500
dpa limit	200	200	200	200	60	60	150

Table IV.2

Structural Material Compositions

Ferritic Steel (16)		MANET (17)		V-4Cr-4Ti (19)		Silicon Carbide (5)		
7.57 g/cm^3		7.76 g/cm^3		5.398 g/cm^3		2.50 g/cm^3		
	w/o		w/o		w/o		a/o	
Fe	Remainder	Fe	Remainder	V	Remainder	Si	50	
C	0.08-0.12	C	0.13	Cr	4	C	50	
Si	0.01-0.06	Cr	10.6	Ti	4	Impurities		
Cr	7.5-8.5	Ni	0.87	Si	0.05		AIRIES-I (5)	Fetter (20)
W	1.8-2.2	Mo	0.77	impurities			wppm	appm
V	0.15-0.25	V	0.22	Nb	1 ppm	Fe	11	1
Ta	0.01-0.06	Nb	0.16			Co	3	0.2
Impurities (16)	w/o	Si	0.37			Na		0.045
Mn	<0.5 (0.5)	Mn	0.82			K		0.06
P	<0.01 (0.01)	S	0.004			Sc		0.04
S	<0.01 (0.01)	P	0.005			Mn		0.02
Mo	LAP (4 ppm)	B	0.0085			Cr		1
Ni	<0.1 (0.1)	N	0.003			As		0.002
Nb	LAP (.5ppm)	Al	0.054			Sb		0.003
N	<0.001(0.001)	Co	0.01			W		0.01
Al	LAP (0.02)	Cu	0.015			Au		0.00003
		Zr	0.053			Ta		0.08

Table IV.2 (cont.)

Structural Material Compositions

316SS (21)		VA64 (23)		PCA (22)		D.S. Copper (21)	
7.86 g/cm^3		7.72 g/cm^3		7.97 g/cm^3		7.97 g/cm^3	
	w/o		w/o		w/o		
Fe	Remainder	Fe	Remainder	Fe	Remainder	Cu	Remainder
Cr	17.4	Cr	20.76	Ni	16	Al_2O_3	0.2 w/o Al
Mn	1.8	Ni	0.25	Cr	14	impurities (26)	w/o
Ni	12.3	Mn	10.59	Mn	2	Zr	0.15
Mo	2.5	Si	0.12	Mo	2	Fe	0.0022
Co	0.17	S	0.006	Si	0.5	S	0.0012
Cu	0.2	P	0.024	Ti	0.3	Ag	0.0012
Si	0.46	Mo	1.04	V	0.1	Ni	0.0005
B	0.001	V	1	W	0.05	As	0.0005
C	0.024	N	0.5	Al	0.03	Sb	0.0005
N	0.06	C	0.62	Co	0.03	Pb	0.0005
S	0.002	Nb	1.2	Nb	0.03	Se	0.0002
P	0.027	Co	0.03	Cu	0.02	Sn	0.0001
		Al	0.001	As	0.02	Te	0.0001
		Impurities (23)	w/o	N	0.01	Bi	0.0001
		Sn	0.005	P	0.01	Mn	0.00005
		Ba	0.0002	Ta	0.01		
		Sm	0.00005	B	0.005		
		Bi	0.0005	C	0.005		
		Tb	0.00005	S	0.005		
		Eu	0.00002	Zr	0.005		
		Ir	0.00001	Sn	0.005		
		Ag	0.00005	Sb	0.001		
				Ba	0.001		
				Tb	0.001		
				Ir	0.001		
				Pb	0.001		
				Bi	0.001		
				K	0.0003		
				Cd	0.0002		
				Ag	0.0001		

Table IV.3
Breeding Material Compositions

Lithum Oxide (26) (Li_2O)		Lithium (4) (Li)		Lithium Zirconate (Li_2ZrO_3) (5)		Lithium Lead (3) ($Li_{17}Pb_{83}$)		
2.10 g/cm^3		0.53 g/cm^3		4.16 g/cm^3		9.51 g/cm^3		
	a/o		w/o		a/o	Pb	83	
Li	66.7	Li	100	Zr	16.7	Li	17	90% Li-6
O	33.3	impurities (26)	w/o	Li	33.3 80% Li-6		Holdren (26)	Fetter (20)
impurities	w/o	C	0.001	O	50	impurities		
K	0.037	N	0.005	impurities	wppm	Sr	0.1	
Ca	0.021	Na	0.03	K	370	P	0.05	
Cl	0.01	Si	0.008	Ca	210	Zn	0.05	
Fe	0.01	Cl	0.004	Cl	100	S	0.03	
pb	0.008	K	0.02	Fe	100	K	0.03	
na	0.005	Ca	0.03	Pb	80	As	0.03	0.00012
al	0.002	V	0.0003	Na	50	Zr	0.03	
mn	0.002	Cr	0.0002	Al	20	O	0.026	
ni	0.002	Fe	0.001	Mn	20	Na	0.01	0.00018
si	0.001			Ni	20	Ca	0.01	0.00018
cu	0.0006			Si	10	Fe	0.01	
				Cu	5	Ba	0.01	
						Bi	0.01	0.004
						Al	0.005	
						Cd	0.005	
						Ti	0.003	
						V	0.003	
						Co	0.003	
						Mo	0.003	
						Sb	0.003	0.0003
						Cl	0.002	
						Cr	0.002	
						Be	0.001	
						B	0.001	
						N	0.001	
						Mg	0.001	
						Si	0.001	
						Mn	0.001	
						Ni	0.001	
						Cu	0.001	0.0002
						Ag	0.001	0.001
						Sn	0.001	

Table IV.4

Other Material Compositions

Beryllium (20) (Be)		Calcium Oxide (19) (CaO)		Alumina (28) (Al_2O_3)		Lead (20) (Pb)	
1.85 g/ cm^3		3.315 g/ cm^3		3.97 g/cm^3		11.35 g/cm^3	
	w/o		a/o		a/o		w/o
Be	100	Ca	50	Al	40	Pb	100
impurities	wppm	O	50	O	60	impurities	wppm
Li	3					Cu	2
B	2					Ag	10
C	1000					Sb	3
N	300					Bi	40
Mg	800						
Al	900						
Si	600						
Ca	200						
Cr	100						
Mn	150						
Fe	600						
Co	5						
Ni	300						
Cu	100						
Zn	200						
Mo	20						
Cd	2						
Pb	20						

CHAPTER V

WASTE DISPOSAL PARAMETERS

There are many activation parameters that can be evaluated. The parameters of interest in this analysis were parameters related to radioactive waste disposal. The reason for focusing on waste disposal was because this is the key to fusion realizing its potential as an environmentally benign energy source and avoiding the long-term/deep repository waste disposal issue that is currently faced by fission reactors. The most effective method of handling waste is to reduce and/or eliminate it through an effective design and choice of materials.

While there are no accepted national or international criteria for the disposal of fusion wastes, the criteria presently used for other forms of radioactive waste provides some perspective for fusion radioactive waste disposal. The low-level waste criteria for several countries (29) are listed in table V.1. There are several parameters which play a major role in current radioactive waste handling and disposal. These parameters are waste disposal rating, specific activity, total activity, contact dose, life cycle volume, and deep disposal index.

Since there are no large fusion neutron sources in existence, regulatory limits for disposal of the majority of isotopes that will be produced do not exist. The waste disposal rating (WDR) is defined in terms of the maximum allowable dose that could be received by an inadvertent intruder to an abandoned waste site. Fetter (30), based on the nuclear regulatory commission (NRC) intruder dose scenario (31), calculated the concentration of each isotope which would result in a 500 mrem/yr whole body dose or 1500 mrem/yr dose to a single organ to an inadvertent intruder. In the inadvertent intruder scenario, there is construction of a house on the waste disposal site after the period of institutional control, assumed to be 100 years. Construction workers are exposed to gamma radiation from the waste and inhale suspended waste particles. If the waste is still stabilized, they recognize it as radioactive waste and construction stops after 6 hours. Class C (31) waste, which is the most radioactive class of waste still considered low-level, is assumed to be stabilized for 500 years. If the waste is no longer stabilized, the house is completed with construction taking 500 hours. The house is then occupied and the residents of the house are exposed to direct gamma radiation, suspended waste particles, and grow half of their food on the waste site.

From this type of analysis, the limiting specific activities for the various radioisotopes can be established and the correponding critical concentrations can be calculated. The WDR is then defined as the ratio of the actual concentration to the critical concentration summed over all radioisotopes present. Thus, satisfaction of the dose limits to an inadvertant intruder corresponds to WDR ≤ 1.

Table V.2 lists the critical concentrations of the various radioisotopes taken from the lower limit of values given in Fetter (30). These values were calculated for activated metals. The results will be lower for wastes which are not activated metals because of lower stability of these wastes. These were used as the near-surface burial limits, and the specific activities of the different components in each design were determined by REAC*3 (11). Using these values, the waste disposal rating (WDR) for each component was determined.

The waste disposal rating was often dominated by a few elements and therefore could be reduced drastically if these elements could be replaced, if alloying elements, or eliminated if impurities. The WDR of the structural materials including impurities will be given by element in chapter VII. The values given are the amount of the WDR due to that specific element. This allowed determination of the key elements for achieving a LLW classification.

The life cycle volume, as the name implies, is the total waste volume generated during the life of the reactor. It is the component volume times the number of that component used during the life of the plant, based on lifetime consideration such as radiation damage.

The deep disposal index is a parameter which gives some sense of the relative hazard of the high level waste. The deep disposal index is calculated by summing the life cycle volume multiplied by the waste disposal rating for all components with a WDR greater than 1.0.

The specific or total activity of the waste gives only a general representation of the waste hazard, but these values are often quoted. In some countries, these parameter may form the basis for waste classification (29). The total activity was calculated by taking the specific activity, calculated with REAC*3, and multiplying by the life cycle volume. For components which are replaced, this is an overestimate because of the decay from the time of replacement to the end of the plant life.

Since tritium ($T_{1/2}$=12.3 years) is not important on the long time scales of concern for waste disposal, it is not included in the activation calculations.

When handling radioactive material is being considered, one of the most important parameters is the contact dose. This determines the amount of shielding required, if remote handling is required, if the material can be recycled, etc. Therefore, this is a strong factor in determining the cost of handling and transporting the waste. The contact dose is defined as the photon dose at the surface of an uniformly contaminated semi-infinite slab of the material. Contact dose is also a basis for waste classification in some countries (29).

All parameters are calculated based on several assumptions. The following is a list of these assumptions. Solid breeding materials are not recycled. All liquid materials are removed and handled separately. Water is treated and released to the environment. Lithium and lithium lead are used for the life of the plant and the quantity used is twice the volume present in the reactor. They are then disposed of as radioactive waste. All components are disposed of as units. No credit is taken for dilution. The entire blanket region inside the vacuum vessel is removed at each blanket replacement.

Table V.1

Low-Level Waste Criteria (29)

Country	Waste		Criteria
USA			Isotope Specific
Japan	Solid		1-10^{-3} Ci/m^3
	Liquid		10^{-3}-10^{-6} Ci/m^3
	Gaseous		10^{-6}-10^{-9} Ci/m^3
U.K.	Alpha		<0.11 Ci/t
	Beta, Gamma		<0.32 Ci/t
France			Isotope Specific
FRG			Isotope Specific
Sweden	Alpha		0.27 Ci total site
	Beta, Gamma		270 Ci total site
USSR	Solid	Alpha	0.01 - 0.0001 Ci/t
		Beta	0.1 - 0.001 Ci/t
		Gamma	0.3 - 0.0003 mSv/hr
	Liquid		<10^{-2} Ci/m^3
IAEA proposal	Solid		<2 mSv/hr
	Liquid		10^{-3}-10^{-6} Ci/m^3
	Gaseous		<10^{-10} Ci/m^3

Table V.2

Near-Surface Disposal Specific Activity Limits (30)

Isotope	Half-life (yrs)	Limit (Ci/m^3)	Isotope	Half-life (yrs)	Limit (Ci/m^3)	Isotope	Half-life (yrs)	Limit (Ci/m^3)
h 3	1.23E+01	TMSA[1]	sn121m	5.50E+01	7.00E+05	pb210	2.23E+01	3.00E+07
be 10	1.60E+06	5.00E+03	sn126	1.00E+05	1.00E-01	bi207	3.22E+01	9.00E+03
c 14	5.70E+03	6.00E+02	i 129	1.57E+07	2.00E+00	bi210m	3.00E+06	1.00E+00
al 26	7.20E+05	9.00E-02	cs135	3.00E+06	1.70E+03	po209	1.02E+02	3.00E+03
si 32	1.04E+02	6.00E+02	cs137	3.00E+01	5.00E+04	ra226	1.60E+03	1.00E-01
cl 36	3.01E+02	1.00E+01	la137	6.00E+04	2.00E+02	ra228	5.80E+06	3.00E+07
ar 39	2.69E+02	2.00E+04	la138	1.06E+11	1.50E-01	ac227	2.18E+01	5.00E+05
ar 42	3.30E+01	2.00E+04	pm145	1.77E+01	1.00E+09	th229	7.30E+03	2.00E+00
k 40	1.30E+09	2.00E+00	pm146	5.50E+00	3.20E+09	th230	7.40E+04	3.00E-01
ca 41	1.03E+05	1.00E+04	sm146	1.03E+06	1.70E+02	th232	1.40E+10	1.00E-01
ti 44	4.70E+01	2.00E+02	sm147	1.06E+11	1.70E-01	pa231	6.28E+04	7.00E-01
mn 53	TMSA[1]	1.30E+04	sm151	9.00E+01	5.00E+07	u 232	6.89E+01	3.00E+01
fe 60	1.00E+05	1.00E-01	eu150m	3.60E+01	3.00E+03	u 233	1.59E+05	2.00E+01
co 60	5.30E+00	3.00E+08	eu152	1.33E+01	3.00E+05	u 234	2.45E+05	9.00E+01
ni 59	7.50E+05	9.00E+02	eu154	8.80E+00	5.00E+06	u 235	7.04E+08	2.00E+00
ni 63	1.00E+02	7.00E+05	gd148	9.80E+01	2.00E+05	u 236	TMSA[1]	1.20E+03
se 79	6.50E+05	5.00E+01	gd150	1.80E+06	2.00E+03	u 238	TMSA[1]	6.30E+00
kr 81	2.10E+05	3.00E+01	tb157	1.50E+02	5.00E+03	np236	1.15E+05	1.00E+00
kr 85	TMSA[1]	6.00E+08	tb158	1.50E+02	4.00E+00	np237	2.10E+06	1.00E+00
rb 87	TMSA[1]	1.30E-01	dy154	1.00E+07	1.00E+03	pu238	8.77E+01	7.00E+04
sr 90	2.85E+01	8.00E+05	ho166m	1.20E+03	2.00E-01	pu239	2.41E+04	1.00E+03
zr 93	TMSA[1]	1.70E+04	lu176	TMSA[1]	5.60E-01	pu240	6.60E+03	1.00E+03
nb 91	6.80E+02	2.00E+02	hf178m	3.10E+01	9.00E+03	pu241	1.44E+01	2.00E+03
nb 92	3.60E+07	2.00E-01	hf182	9.00E+06	2.00E-01	pu242	3.73E+05	1.00E+03
nb 93m	TMSA[1]	2.40E+03	re186m	2.00E+05	2.00E+01	pu244	8.08E+07	9.00E-01
nb 94	2.00E+04	2.00E-01	re187	TMSA[1]	1.00E+00	am241	4.32E+02	5.00E+01
mo 93	3.50E+03	4.00E+03	os194	TMSA[1]	7.10E+09	am242m	1.41E+02	3.00E+02
tc 97	2.60E+06	4.00E-01	ir192m	2.41E+02	1.00E+00	am243	7.40E+03	2.00E+00
tc 98	4.20E+06	1.00E-02	pt190	TMSA[1]	6.50E-02	cm243	2.85E+01	6.00E+02
tc 99	2.13E+05	6.00E-02	pt193	5.00E+01	2.00E+08	cm244	1.81E+01	5.00E+05
pd107	6.50E+06	9.00E+02	hg194	5.20E+02	5.00E-01	cm245	8.50E+03	5.00E+00
ag108m	1.27E+02	3.00E+00	pb202	5.30E+04	6.00E-01	cm246	4.80E+03	8.00E+02
cd113m	TMSA[1]	2.00E+09	pb205	TMSA[1]	1.00E+03	cm248	3.40E+05	8.00E+02

1. Theoretical Maximum Specific Activity (TMSA) does not exceed dose limits to inadvertent intruder.

CHAPTER VI

MODEL COMPARISONS

VI.A. TBR Model Comparisons

The neutronics model used was a one-dimensional cylindrical representation of a toroidal fusion reactor centered on the plasma centerline. This is referred to as the toroidal model. This model is shown in figure VI.1.

One of the important quantities calculated was the tritium breeding ratio (TBR). In order to verify the neutronics model, the results were compared with the TBR values reported for the original reference designs. For each reference design, a different model was used. In one case a 3-D Monte Carlo method was used and in the others various 1-D representations were used.

For the Argonne design, a 1-D cylindrical representation of a toroidal fusion reactor centered on the flux core centerline was used (19). This is referred to as the poloidal model and is shown in figure 2. To compare cross section sets, the ANL poloidal model was run using the MATXS10 cross sections. In the ANL calculations, a TBR of 1.222 was reported (19). Using the same poloidal model a TBR of 1.243 was calculated. Then the TBR was calculated using the toroidal model, which yielded a TBR of 1.203.

In the European design (3), a very detailed 3-D Monte Carlo calculation was performed for a model including divertor, ports, etc. A TBR of 1.190 was reported. In this analysis, using the toroidal model, a TBR of 1.380 was calculated. This model assumes full coverage of the torus by the blanket, and therefore overestimates the actual TBR.

In the Japanese design (2), the same type of poloidal model that was used by Argonne appears to have been used. A TBR of 1.420 for the full torus was reported. Based on the results reported, the value for the outboard blanket alone was 1.336 (number of tritium produced in outboard blanket / number of fusion neutrons incident on outboard blanket). In this analysis, using the toroidal model, the calculated TBR of the outboard blanket was 1.335.

In the AIRIES-I study a 1-D toroidal model appears to have been used (5). They calculated a TBR of 1.214. In this analysis, the calculated TBR was calculated to be 1.222.

The results of this comparison are tabulated in table VI.1. In this analysis, the TBR was an important parameter for scaling the blanket size. In comparing the calculated results with the values reported for the reference designs, it was judged that agreement to be sufficient to confirm the adequacy of the model for this purpose. Sufficient blanket thickness was chosen to achieve a TBR of 1.20 using the one-dimensional toroidal model. This takes into account the effect of divertors, ports and other regions unavailable for tritium breeding and to still allow for a TBR significantly in excess of unity.

Table VI.1

TBR Comparison

Design	Reference TBR	Calculated TBR	Model Used	Blankets Modeled
Japanese (2)	1.420		Poloidal Model	Inboard & Outboard
	1.336	1.335	Toroidal Model	Outboard
Argonne (19)	1.222	1.243	Poloidal Model	Inboard & Outboard
		1.203	Toroidal Model	Outboard
European (3)	1.190		3-D Monte Carlo	Inboard, Outboard & Divertor
		1.380	Toroidal Model	Outboard
AIRIES-I (5)	1.214	1.222	Toroidal Model	Outboard

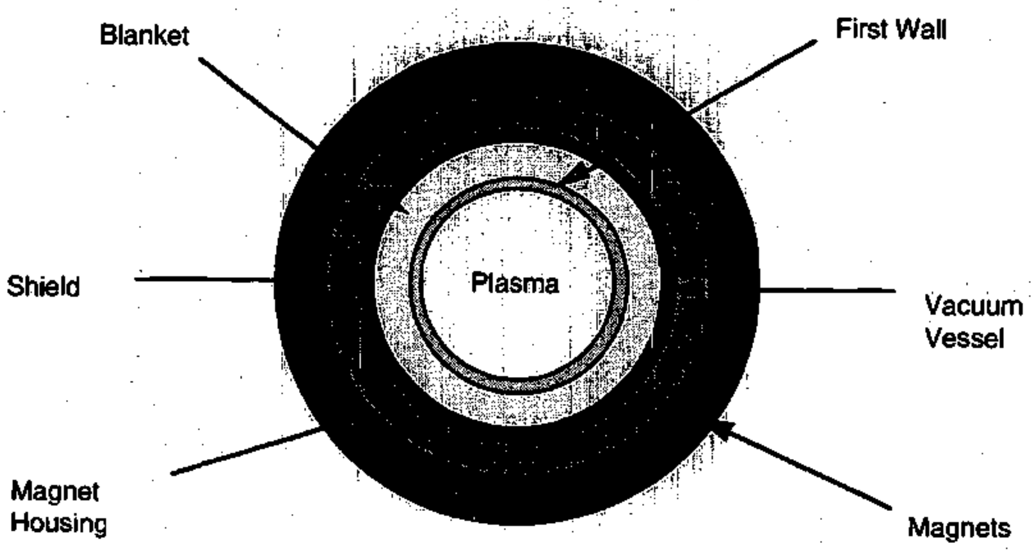

Figure VI.1

Toroidal Model

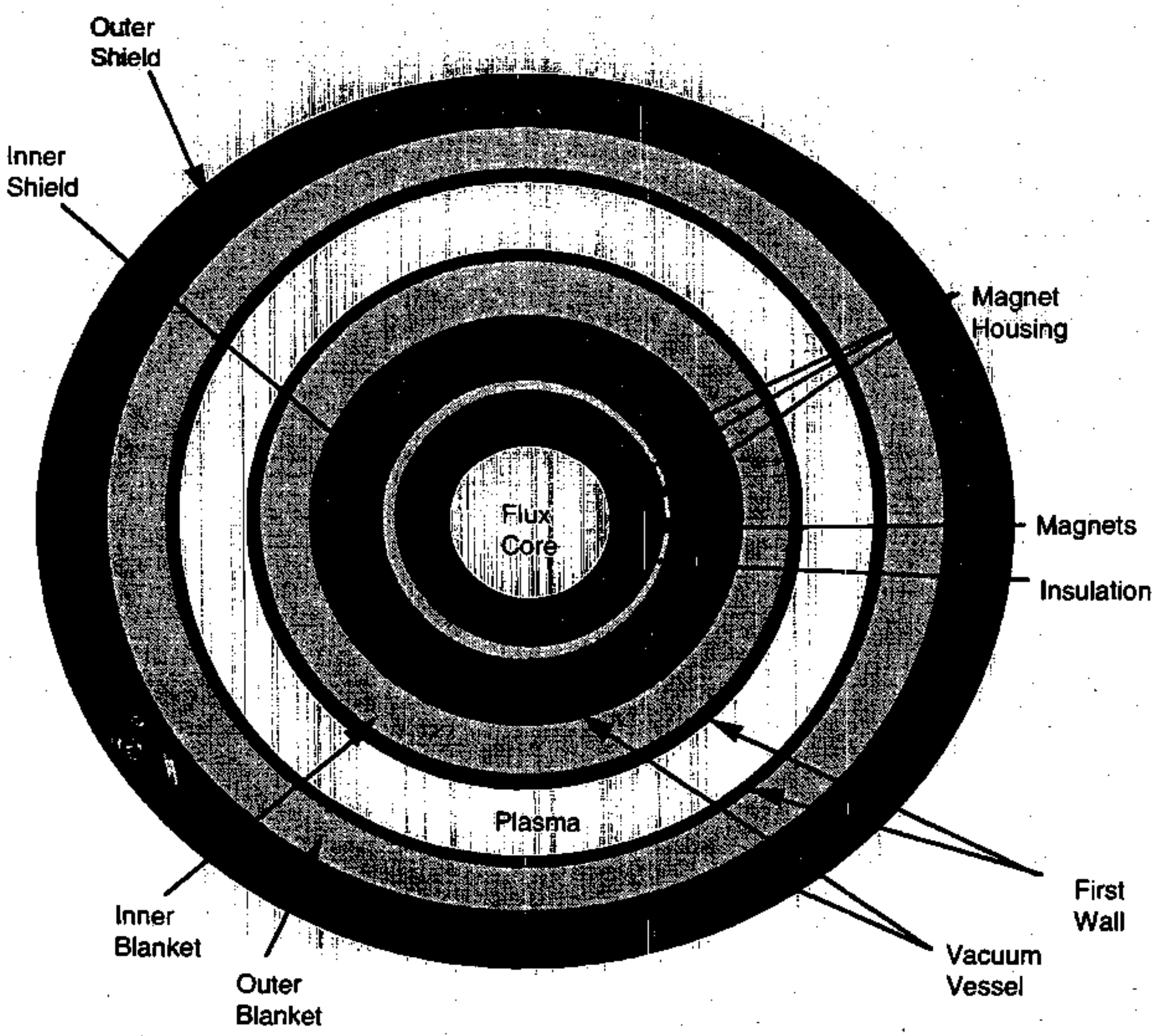

Figure VI.2

Poloidal Model

VI.B. Activation Model Comparisons

Kinzig et al. (22) performed activation calculations on a PCA/lithium design. The results included total inventory and contact dose; and waste disposal rating could be inferred. Exact details of their model were not available. Table VI.2 lists a comparison of the results. The Kinzig values listed in table VI.2 were estimated from figures in that work (22).

In general, the waste disposal ratings for the various components showed good agreement and in general were within the accuracy with which the values could be estimated from Kinzig's figures.

There were some differences between the contact doses, with this analysis having consistently higher results. Most of the time, this analysis yielded results 2-4 times higher , but the maximum difference was 40 times higher. The contact dose in the blanket was higher than in the first wall in Kinzig. This could not occur with the model used in this analysis and clearly represents a difference in modeling (i.e. other materials present, or activation for longer than stated).

The contact doses in the first wall showed good agreement at all times. The values were typically within the accuracy with which the values could be estimated from the figures in Kinzig.

The results of this comparison are shown in table VI.2. This comparison generally supports the adequacy of this model. Reference design results are compared with values given in the reference reports when available.

Table VI.2

Activation Comparison

		First Wall - PCA		Blanket - PCA		Manifold #1 - PCA	
	Shutdown Time	Kinzig (22)	Calculated	Kinzig	Calculated	Kinzig	Calculated
Contact Dose (mSv/hr)	1 hour	1.20E+07	1.44E+08	3.00E+07	6.22E+07	1.00E+06	1.36e+07
	1 day	5.50E+06	1.25E+08	1.55E+07	2.97E+07	2.10E+05	7.04e+06
	1 week	5.00E+06	6.71E+07	1.50E+07	3.01E+07	2.00E+05	5.87e+06
	1 month	4.00E+06	5.74E+07	1.30E+07	2.36E+07	1.50E+05	6.12e+06
	1 year	1.10E+06	1.57E+07	3.00E+06	5.91E+06	8.00E+04	1.17e+06
	30 years	9.00E+03	1.14E+05	2.80E+04	4.66E+04	9.00E+02	9.87e+03
Waste Disposal Rating		559	710	307	425	193	213

		Manifold #2 Fe-2Cr-1V		Shield Fe-2Cr-1V	
	Shutdown Time	Kinzig	Calculated	Kinzig	Calculated
Contact Dose (mSv/hr)	1 hour	2.50E+05	8.39E+05	3.00E+04	8.89E+04
	1 day	4.10E+04	1.57E+05	2.40E+03	9.48E+03
	1 week	4.00E+04	1.52E+05	2.20E+03	7.84E+03
	1 month	3.50E+04	1.37E+05	1.80E+03	5.81E+03
	1 year	2.00E+04	5.41E+04	4.00E+02	8.42E+02
	30 years	6.00E+00	8.13E+01	4.00E+00	8.43E+00
Waste Disposal Rating		1.4	2.59	0.6	0.2

CHAPTER VII

DEMONSTRATION REACTOR DESIGNS

Each design was sized according to the material properties by adjusting dimensions to satisfy physics and engineering constraints. The calculational model was developed by Stacey (6). The model iterates on the various physics and engineering constraints to determine the minimum major radius device that will satisfy these constraints.

The structural components of the central solenoid, toroidal field coil and support structure were sized to satisfy ASME code requirements for SS316LN, taking into account reduction of the stress allowable S_m due to crack growth for cyclic operation. Adequate conductor cross section was allowed to accommodate the ITER-EDA Outline Design current density (32) and a maximum toroidal field of B=12 T. The number of pulses used for the stress allowable reduction is determined from the total operating time and the pulse length of 10^4 sec, plus 10^4 shakedown pulses.

The flux core was sized to provide the volt-seconds required to induce and maintain the plasma current during the burn pulse, taking into account bootstrap (33) and non-inductive (34) current drive, and allowing for 50% reduction in startup resistive volt-seconds due to startup assist. An upper limit of 80% bootstrap current was imposed to take into account the necessity to provide some non-inductive current drive to tailor current profiles. The pulse length was determined to minimize major radius from a tradeoff between the increasing flux core needed for longer pulses and the increasing magnet structure needed for a larger number of pulses.

The shield was sized to limit peak nuclear heating and neutron fluence in the inboard TF coil to 1 mW/cm^3 and $2x10^{22}$ n/m^2, respectively (35). The blanket was sized to attenuate 95% of the nuclear energy flux and to achieve a (1D model) tritium breeding ratio ≥ 1.20 in order to insure tritium self-sufficiency.

The vacuum vessel, located between the blanket and the shield, was sized to withstand an overpressure of 10 atmospheres.

The first wall heat removal element and strongback were sized to satisfy ASME code stress allowable under coolant and disruption pressures. The plasma minor radius must be large enough to satisfy the q_{95} constraint and also to result in a first wall peak heat flux below the ASME code thermal stress-limited value. A tube bank model that has been adjusted to match more exact models and a peaking factor of 2.0 were used for the heat flux calculations.

The major radius was then determined by summing the constituent thicknesses and adding 10 cm to allow for gaps between the first wall and toroidal field coil.

The plasma temperature was set at T = 10keV and the plasma density was determined from the specific fusion power. In order that each design point would have the same confinement potential, the plasma current was then calculated, using the ITER89P scaling law (33) with the appropriate confinement enhancement factor, H, to yield an energy confinement time $\tau = 3.0s$, which provides some margin for power balance and the τ obtained from the scaling law. The solution is constrained to satisfy the specified β_n-limit. A 10% He concentration plus an oxygen impurity $Z_{eff} = 1.5$ are assumed. The ITER form of the physics constraints (33) and the general ITER design procedures (35) have been followed.

The compositions and resulting radial dimensions of the components in each design are given in tables VII.1.a-b. The resulting values of key parameters for the DEMO's are given in table VII.2.

Table VII.3 lists the average neutron load to the first wall, divertor wall, and divertor plate for each design. The blanket, vacuum vessel, and shield are subject to the attenuated first wall load. The calculated lifetime for the first wall, divertor wall, and divertor plate are also given. The vacuum vessel and shield are designed to last for the entire 10.0 effective full power years (EFPY) of operation for the demo design being modeled.

Table VII.1.a

Compositions and Dimensions of the Reference Reactor Designs

	R1		R2		R3		R4	
Component	Materials	Thickness (cm)	Materials	Thickness (cm)	Materials	Thickness (cm)	Materials	Thickness (cm)
First Wall	Ferritic Steel/ H_2O	2.68	MANET /H_2O	2.24	V/Li	2.52	Silicon Carbide/ He	2.43
Divertor [1] Plate	DSCu/ H_2O	4.24	DSCu/ H_2O	4.32	DSCu/ Li	4.43	DSCu/ He	3.82
Divertor Wall	Ferritic Steel/ H_2O	2.68	MANET /H_2O	2.24	V/Li	2.52	Silicon Carbide/ He	2.43
Blanket	Ferritic Steel/ H_2O/ Li_2O/Be	44.0	MANET /H_2O $Li_{17}Pb_{83}$	40.0	V/Li/ CaO	85.5	Silicon Carbide/ He/Be/ Li_2ZrO_3	96.0
Vacuum Vessel	Ferritic Steel	2.38	MANET	1.85	Ferritic Steel	2.84	Ferritic Steel	2.94
Shield	Ferritic Steel/ H_2O/Pb	63.5	MANET /H_2O /Pb	58.1	Ferritic Steel/ H_2O/Pb	47.4	Ferritic Steel/ H_2O/Pb	41.5

1. DSCu - Dispersion Strengthened Copper

Table VII.1.b

Compositions and Dimensions of the Variant Reactor Designs

	V1		V2		V3		V4	
Component	Materials	Thickness (cm)	Materials	Thickness (cm)	Materials	Thickness (cm)	Materials	Thickness (cm)
First Wall	V/H_2O	2.42	316SS/ H_2O	3.50	PCA/ H_2O	3.52	VA64/ H_2O	1.50
Divertor [1] Plate	DSCu/ H_2O	4.23	DSCu/ H_2O	4.62	DSCu/ H_2O	4.65	DSCu/ H_2O	4.24
Divertor Wall	Ferritic Steel/ H_2O	2.42	316SS/ H_2O	3.50	PCA/ H_2O	3.52	VA64/ H_2O	1.50
Blanket	V/H_2O/ Li_2O/Be	37.3	316SS/ H_2O/ Li_2O/Be	42.0	PCA/ H_2O/ Li_2O/Be	36.0	VA64/ H_2O/ Li_2O/Be	42.5
Vacuum Vessel	Ferritic Steel	2.34	316SS	3.61	PCA	3.55	VA64	1.16
Shield	Ferritic Steel/ H_2O/Pb	72.1	316SS/ H_2O/Pb	60.4	PCA/ H_2O/Pb	63.9	VA64/ H_2O/Pb	67.9

1. DSCu - Dispersion Strengthened Copper

Table VII.2

DEMO Reactor Parameters

Design	R1	R2	R3	R4	V1	V2	V3	V4
Fusion Power (MW)	1500	1500	1500	1500	1500	1500	1500	1500
Lifetime (EFPY)	10	10	10	10	10	10	10	10
Major Radius (m)	6.25	6.22	6.59	6.67	6.26	7.38	7.37	6.26
Minor Radius (m)	1.84	1.81	1.97	1.99	1.85	2.41	2.41	1.84
Plasma elongation	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Maximum Toroidal Field (T)	12	12	12	12	12	12	12	12
Plasma Current (MA)	12.9	13.0	13.1	13.1	12.9	15.5	15.6	12.9
β_n	3.89	3.75	4.00	4.00	3.92	2.96	2.93	3.90
H ITER89P	3.00	3.00	2.79	2.75	3.00	2.01	2.00	3.00
Auxiliary Power (MW)	100	100	100	100	100	100	100	100
Maximum First Wall Heat Flux (MW/m^2)	0.695	0.712	0.618	0.603	0.692	0.450	0.450	0.694
Average First Wall Neutron Load (MW/m^2)	1.80	1.84	1.60	1.56	1.79	1.16	1.16	1.80

Table VII.3

Neutron Loads and Component Lifetimes

		R1	R2	R3	R4	V1	V2	V3	V4
First Wall	Neutron Load (MW/m^2)	1.80	1.84	1.60	1.56	1.79	1.16	1.16	1.80
	Life (EFPY)	5.28	4.41	5.46	5.86	5.1	2.41	4.02	1.61
Blanket	Life (EFPY)	7.39	5.94	6.94	6.47	6.45	3.59	5.98	2.05
Divertor Wall	Neutron Load (MW/m^2)	1.37	1.39	1.23	1.20	1.36	0.92	0.92	1.37
	Life (EFPY)	10.0	9.14	10.0	10.0	10.0	4.99	8.31	3.33
Divertor Plate	Neutron Load (MW/m^2)	0.93	0.94	0.85	0.84	0.93	0.68	0.68	0.93
	Life (EFPY)	3.85	3.91	3.70	3.68	3.84	3.19	3.19	3.85

CHAPTER VIII

WASTE DISPOSAL CHARACTERISTICS OF DEMO DESIGNS

This chapter is a discussion of the results for each design which was evaluated. The results are presented in figures in their respective sections. Detailed numerical results are included in appendix A.

VIII.A. DEMO with Reference FeS/Li_2O/H_2O Blanket Design (R1)

The structural material in all components, except for the divertor plate, was ferritic steel (FeS). The structure of the divertor plate was dispersion strengthened copper. In figures VIII.1.a-VIII.1.e, "other" refers to alumina (Al_2O_3), lithium oxide (Li_2O), and beryllium (Be) in the blanket and lead (Pb) in the shield.

The waste disposal rating for the various components are shown in figure VIII.1.a. In this design the first wall, vacuum vessel, and shield will meet the WDR limit of unity. The ferritic steel in the divertor wall will slightly exceed this limit with the specified impurities, but the pure ferritic steel in the divertor wall has a WDR of 0.55, which shows that it could meet the WDR criterion if impurities are controlled.

The elemental contributions to the WDR in the structural materials in each component are shown in figure VIII.1.b. This shows that tungsten (W) is the primary element of concern in the pure structure and the impurities Mo, Nb, and Al contribute significantly to the WDR of ferritic steel.

In the divertor plate, the copper contributes very little to the WDR. The aluminum present in the dispersion strengthener, alumina (Al_2O_3), was responsible for nearly all of the WDR. The concentration of aluminum is 0.2 %. Fetter's results (30) lead to an estimated limit of 0.1 % Al for that particular design. If near-surface burial limits are to be met, it may be necessary to reduce the alumina content if possible or to limit the irradiation of the divertor by design (i.e. distance from plasma, or shortened life).

In the Japanese blanket design, a thermal insulator material would be required to increase minimum temperatures (2). The material that was mentioned (2) was alumina (Al_2O_3). Irradiation of aluminum produces the isotope Al-26, which is a limiting isotope for waste disposal. Even though only a small quantity of alumina would be present in the design, it would be sufficient to prevent near-surface burial. In the absence of this alumina, the blanket would meet the near-surface burial criterion, WDR $\leq$ 1.0. Since there are many other possible thermal insulator materials, it should be reasonable to assume that an acceptable replacement could be found. Therefore, alumina is only considered in this reference case and not included in any subsequent data or figures. In figure VIII.1.a, the contribution to the blanket WDR by other materials is alumina, WDR=3.54; beryllium, WDR= 0.06; and lithium oxide, WDR=0.07. The beryllium and lithium oxide used in this design will easily meet the criterion, WDR$\leq$1.0.

As shown in figure VIII.1.a, the impurities caused large increases in the WDR. In the ferritic steel, this was due to molybdenum (Mo), niobium (Nb), and aluminum (Al). In the divertor plate, silver (Ag) was the primary impurity of concern for the WDR.

In figure VIII.1.a, the WDR's of the first wall and divertor wall showed a large difference despite being the same material and design. This resulted from differences in geometry. The divertor wall is further from the plasma and therefore subject to a lower flux because of the geometric attenuation. The lifetime is limited by the peak flux and the irradiation parameters were evaluated at the average flux. Since the divertor wall is further from the plasma, the peak flux, which determines the irradiation lifetime, is lower and therefore the irradiation time longer. Also, because of geometry, the peak to average ratio for the neutron load on the first wall was greater than on the divertor wall. Since activation calculations are performed with the average flux, the divertor wall receives a larger average fluence than the first wall over their respective lifetimes. In table VII.3, the irradiation time, determined by peak flux, and the average wall load used to perform the activation analysis are given. This resulted in an average neutron load of 9.50 MW-yr/m^2 for the first wall and 13.70 MW-yr/m^2 for the divertor wall.

Figure VIII.1.c shows the specific activity for the various components. The specific activity for each component is given at shutdown and 1, 10, 10^2, 10^3, and 10^4 years after shutdown. By comparison the Japanese low-level waste (LLW) limit for solid wastes is 1 Ci/m^3 (29). Using this criterion, none of the components would be classified as LLW until at least 100 years after shutdown. In this case, impurities do not contribute significantly to the waste activity until

100 years after shutdown. The total activity for each component is shown in figure VIII.1.d.

The contact dose for each component at various times after shutdown is shown in figure VIII.1.e. The IAEA proposal for a LLW limit for solid waste is <2 mSv/hr (29). Based on this criteria, the first wall, divertor wall, and divertor plate would not meet this limit within 100 years after shutdown. The vacuum vessel and shield would meet this limit between 10 and 100 years after shutdown. The blanket will not meet this limit at 100 years if alumina were used, but will be well below this limit at 100 years, without alumina.

The life cycle volume (LCV) for each component is shown in figure VIII.1.f. The volume is also given by material. The lithium oxide and beryllium contributed a large fraction of the volume, but did not significantly contribute to most of the waste disposal parameters that were calculated for the blanket.

The WDR limit , which is based on detailed analysis of the dose that could be received by an inadvertent intruder, is believed to be representative of a realistic criterion for LLW that would qualify for near-surface burial. In terms of WDR, ferritic steel without impurities will meet the near-surface burial criterion, but with the specified impurities, ferritic steel will be very close to this limit and in fact slightly exceeds it in the divertor wall. If a WDR less than unity is to be achieved, it is going to be critical to control impurities. In particular a few such as Mo, Nb, and Ag will need to be controlled to parts per million (ppm) or less.

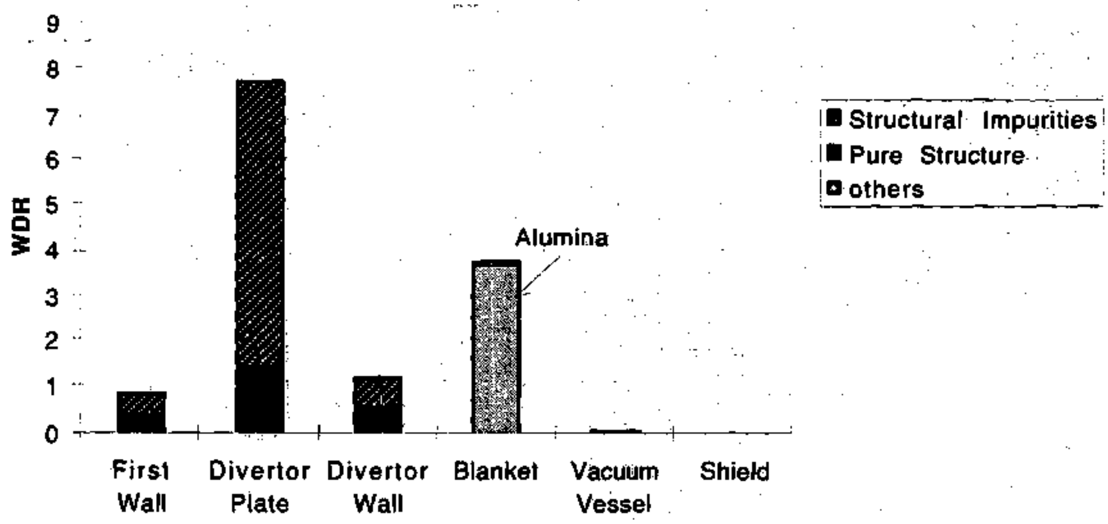

Figure VIII.1.a
Waste Disposal Rating
Reference FeS/Li_2O/H_2O Blanket Design (R1)

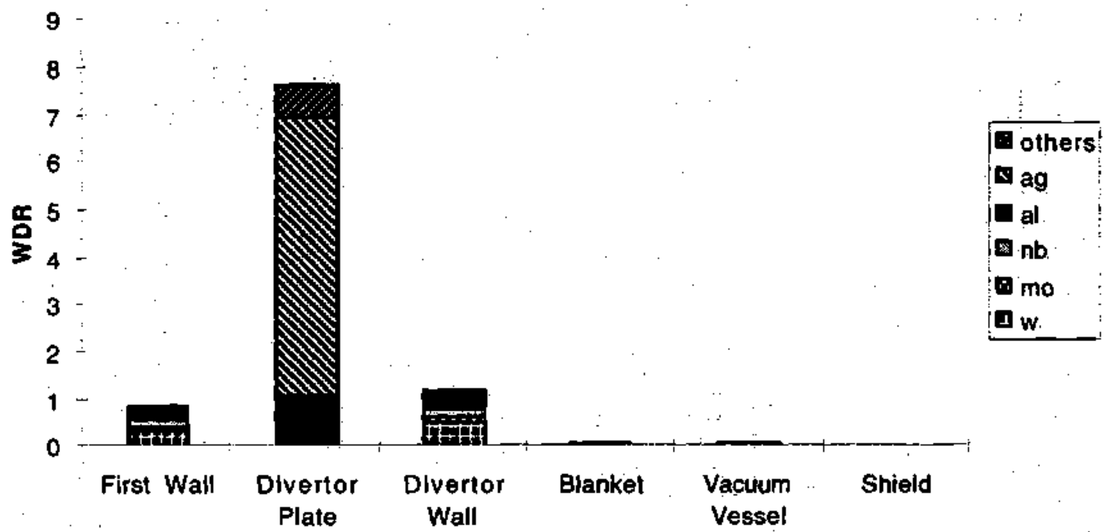

Figure VIII.1.b
Elemental Contributions to Structural Waste Disposal Rating
Reference FeS/Li_2O/H_2O Blanket Design (R1)

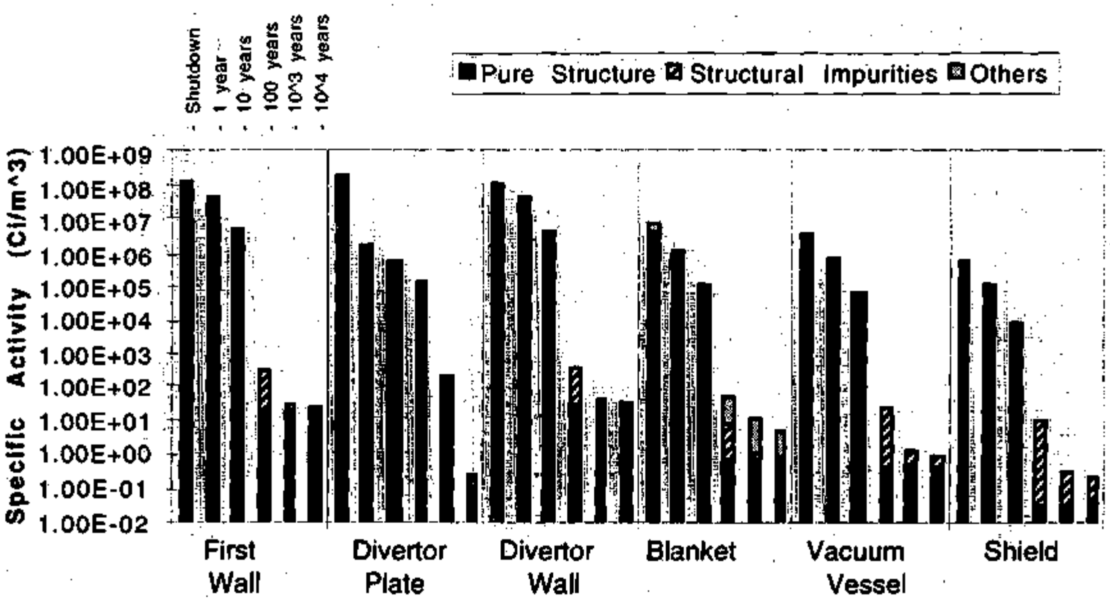

Figure VIII.1.c
Specific Activity
Reference FeS/Li_2O/H_2O Blanket Design (R1)

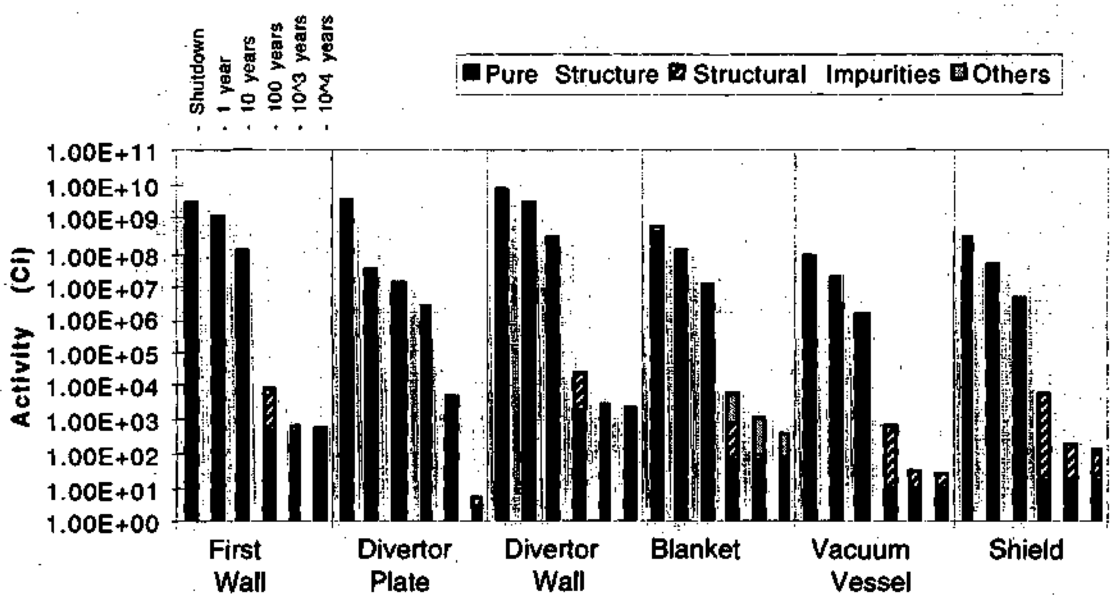

Figure VIII.1.d
Total Activity
Reference FeS/Li_2O/H_2O Blanket Design (R1)

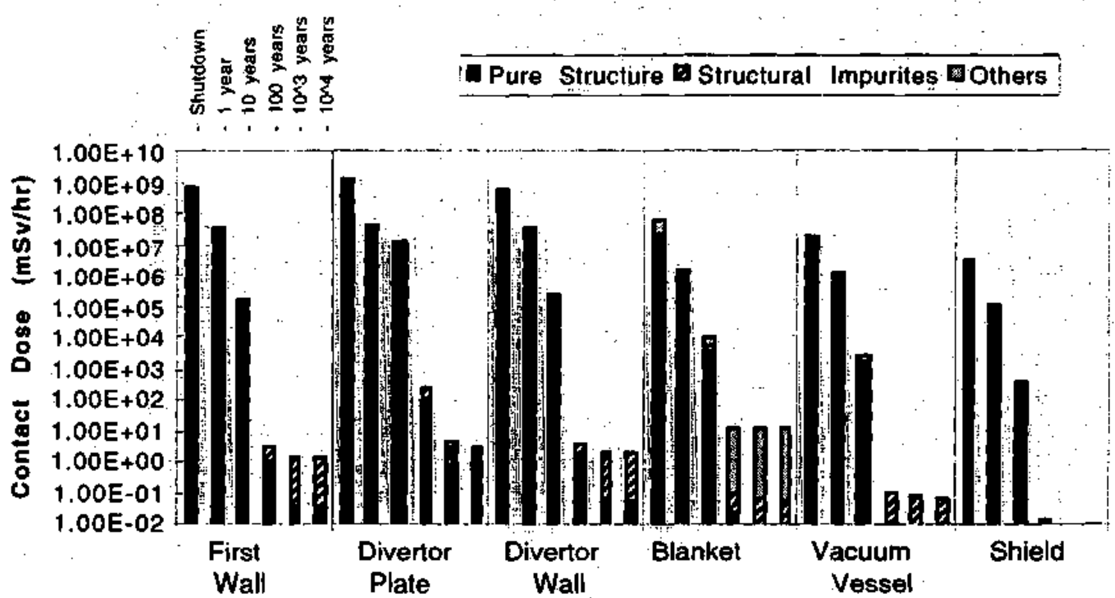

Figure VIII.1.e
Contact Dose
Reference FeS/Li_2O/H_2O Blanket Design (R1)

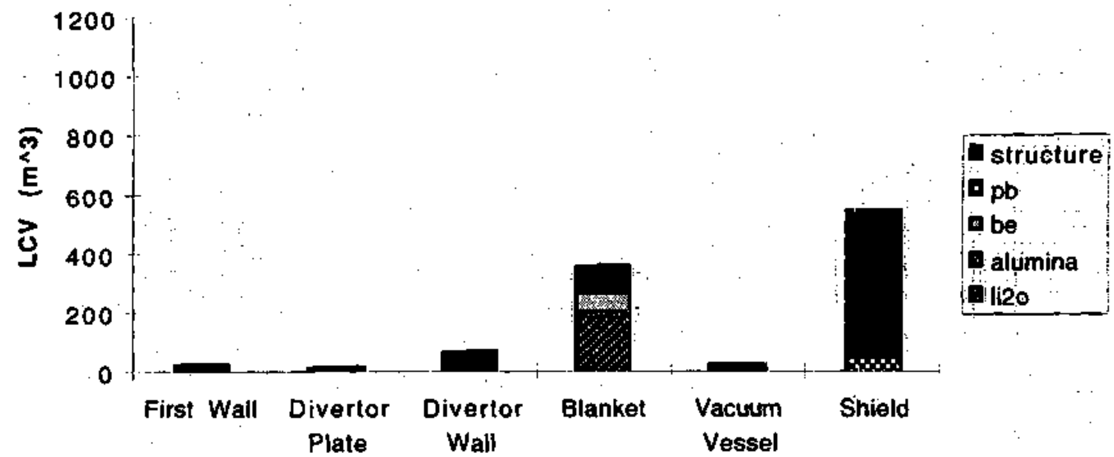

Figure VIII.1.f
Life Cycle Volume
Reference FeS/Li_2O/H_2O Blanket Design (R1)

VIII.B. DEMO with Reference MS/$Li_{17}Pb_{83}$/H_2O Blanket Design (R2)

The structural material in all components, except for the divertor plate, was the martensitic steel (MS), MANET. No information on impurities was found for MANET. Since activation was generally quite high without impurities, they were not considered. The structure of the divertor plate was dispersion strengthened copper. The breeder in this design is a liquid metal, lithium lead. Since it is a liquid, it is assumed that it would be drained from the reactor and disposed of separately from the MANET structure. Therefore, in the blanket, the structural material and lithium lead are treated as separate components, and only the structural material is shown in figures VIII.2.

The waste disposal rating for the various components shown in figure VIII.2.a. In this design, all of the components exceed the WDR criteria of unity by an order of magnitude or more.

The elemental contributions to the WDR in the structural materials in each region is shown in figure VIII.2.b. This figure shows that the WDR for MANET is dominated by the presence of molybdenum (Mo) and niobium (Nb). In this case both are intentional alloys and are present in concentrations several order of magnitude higher than allowable levels.

For the pure lithium lead breeder the WDR was 0.07, which satisfies the WDR criterion. Using Holdren's (26) impurities given in table IV.3, the WDR was increase by 3.95. This was primarily due to the presence of silver (Ag), which contributed 3.56 to the WDR.

The divertor plate is the same as in the previous design and small differences in activation are due to differences in the designs.

The specific activity for the various components is shown in figure VIII.2.c. Using the Japanese LLW limit for solid wastes of 1 Ci/m^3 (29), none of the components would be classified as LLW. The total activity for each component is shown in figure VIII.2.d.

The contact dose for each component is shown in figure VIII.2.e. Based on the IAEA proposal for a LLW limit for solid waste of <2 mSv/hr (29), none of the components would be classified as LLW.

The life cycle volume (LCV) for each component is shown in figure VIII.2.f. The volume is also given by material. As seen in this figure, the lithium lead would constitute a large fraction of the total waste volume.

MANET exceed the LLW criteria by one or more orders of magnitude. It could not be modified to satisfy LLW criteria without significant substitution for the alloying elements, molybdenum and niobium. The lithium lead breeder meets the WDR limit in the pure form, but was well in excess of this value with impurities. Lithium lead could be used and still meet a WDR limit of unity, if the impurities are controled.

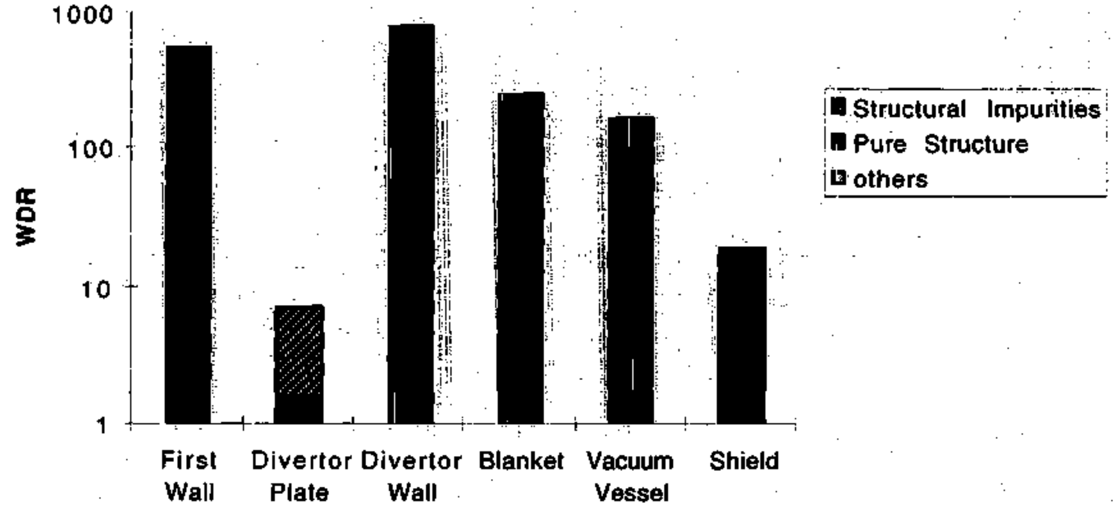

Figure VIII.2.a
Waste Disposal Rating
Reference MS/$Li_{17}Pb_{83}$/H_2O Blanket Design (R2)

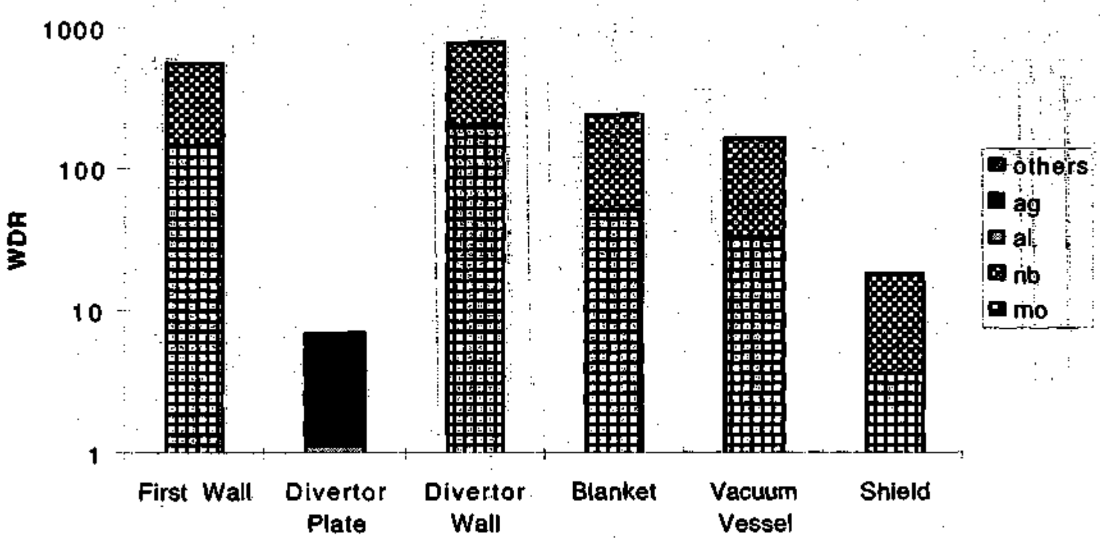

Figure VIII.2.b
Elemental Contributions to Structural Waste Disposal Rating
Reference MS/$Li_{17}Pb_{83}$/ H_2O Blanket Design (R2)

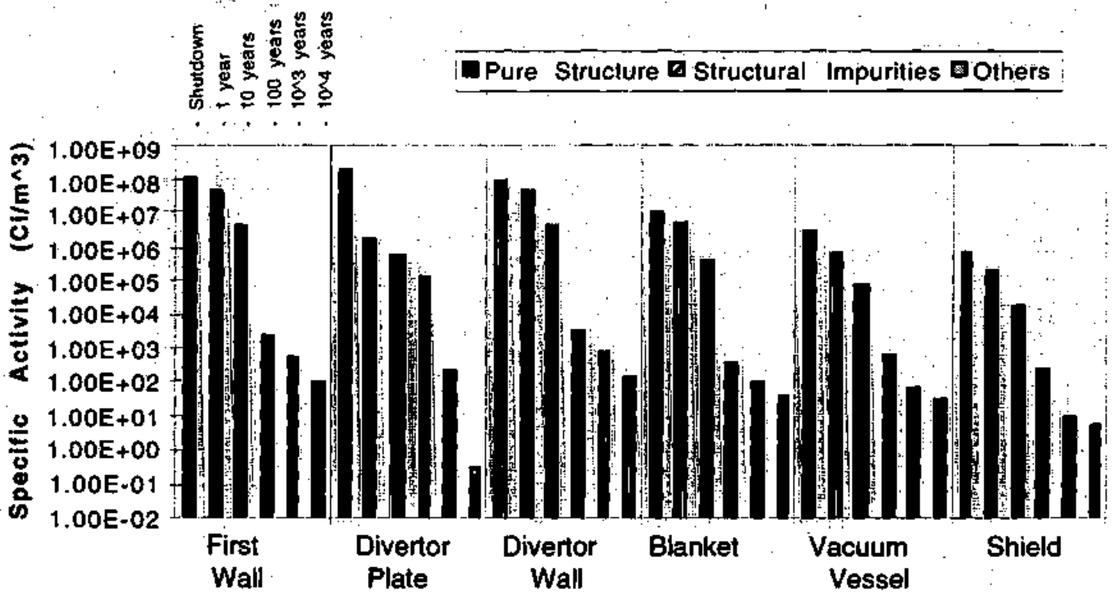

Figure VIII.2.c
Specific Activity
Reference MS/$Li_{17}Pb_{83}$/H_2O Blanket Design (R2)

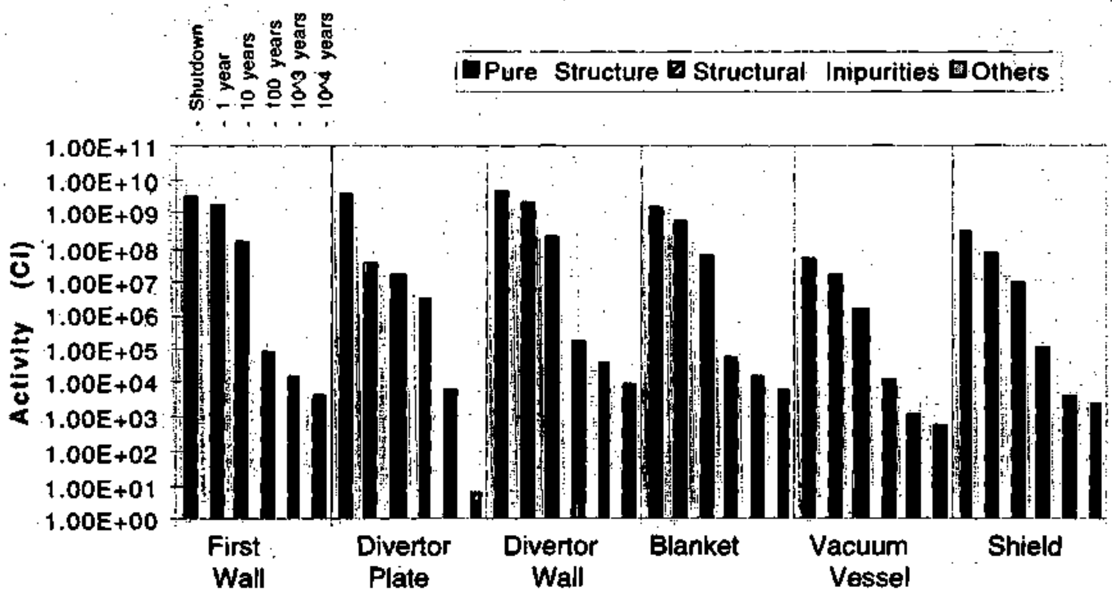

Figure VIII.2.d
Total Activity
Reference MS/$Li_{17}Pb_{83}$/H_2O Blanket Design (R2)

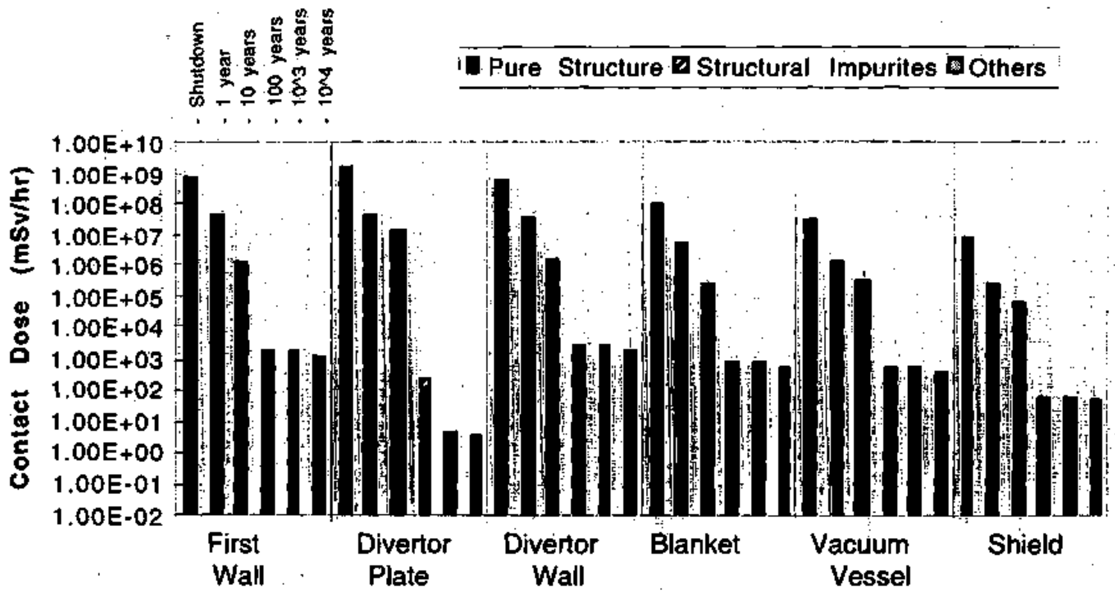

Figure VIII.2.e
Contact Dose
Reference MS/$Li_{17}Pb_{83}$/H_2O Blanket Design (R2)

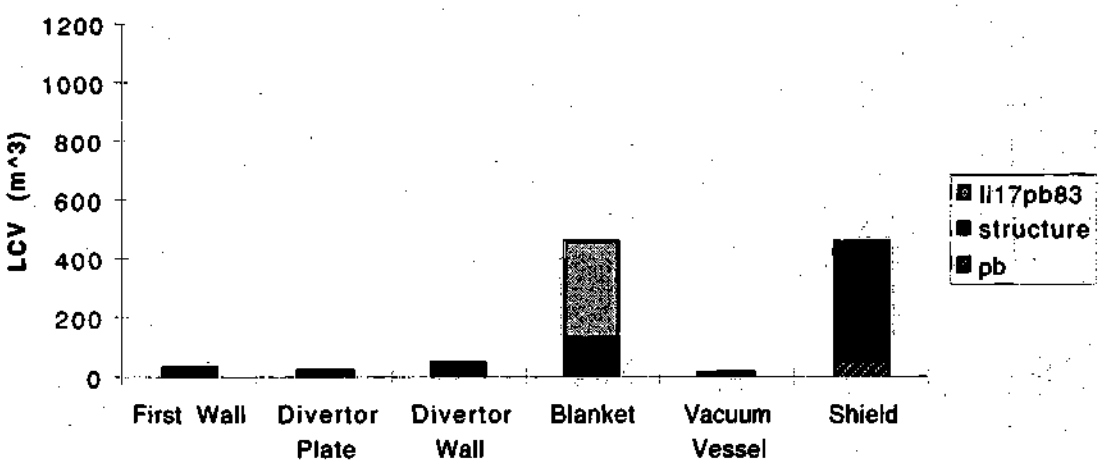

Figure VIII.2.f
Life Cycle Volume
Reference MS/$Li_{17}Pb_{83}$/H_2O Blanket Design (R2)

VIII.C. DEMO with Reference V/Li Blanket Design (R3)

The structural material in the first wall, divertor wall, and blanket was the vanadium alloy, V-4Cr-4Ti. The structural material in the vacuum vessel and shield was the ferritic steel alloy given in table IV.2. The structural material in the divertor plate was dispersion strengthened copper. The breeder in this design is a liquid metal, lithium. Since it was a liquid, it was assumed that the breeder would be drained from the reactor and disposed of separately from the vanadium structure. Therefore, in the blanket, the solid materials and the liquid lithium are treated as separate components and only the solid materials are shown in figures VIII.3. In figures VIII.3.a-VIII.3.e, "other" refers to calcium oxide (CaO) in the blanket and lead (Pb) in the shield.

The waste disposal rating for the various components is shown in figure VIII.3.a. In this design, all components, except the divertor plate, will meet the WDR limit of unity. The vanadium with impurities and the calcium oxide contributed 0.02 and 0.06, respectively, to the WDR of the solid portion of the blanket. The WDR of the liquid lithium breeder with impurities was 0.06.

The elemental contributions to the WDR in the structural materials in each region is shown in figure VIII.3.b. The contribution to the WDR of the primary alloying elements in vanadium is almost zero. The impurity level of 1 ppm Nb was assumed, which results in a WDR of 0.26.

The divertor plate is the same as in the other designs and differences in activation are due to differences in the designs.

The specific activity for the various components is shown in figure VIII.3.c. Using the Japanese LLW limit for solid wastes of 1 Ci/m^3 (29), vanadium will be classified as LLW some time between 10-100 years after shutdown. If this criteria were to be applied, the pure lithium would be classified as LLW, but with the specified impurities, it would not be classified as LLW. The presence of calcium oxide (CaO) as a reflector in the blanket would prevent it from being classified as LLW based on this criterion. The vacuum vessel and shield would not meet this criterion at 100 years because of the impurities in the ferritic steel used as structural material. Figure VIII.3.d shows the total activity for each component. For vanadium, the decay is much more rapid than for the iron-base alloys as shown by the large decrease in activity.

The contact dose for each component is shown in figure VIII.3.e. Using the IAEA proposal for a LLW limit for solid waste of <2 mSv/hr (29), all components, except the divertor plate, would satisfy this criterion between 10 and 100 years after shutdown.

The life cycle volume (LCV) for each component is shown in figure VIII.3.f. The volume is also given by material. In this design, a large neutron reflecting region made of primarily calcium oxide is used inside the vacuum vessel, which contributes to much larger waste volumes in the blanket region than in the previous designs.

Vanadium (V-4Cr-4Ti) appears to be a very good candidate for meeting all low-level waste criteria. The pure material is very low activation and the activation of this material will be dominated by impurities, but with reasonable levels of impurities the WDR≤1.0 criterion for near-surface burial can still be satisfied.

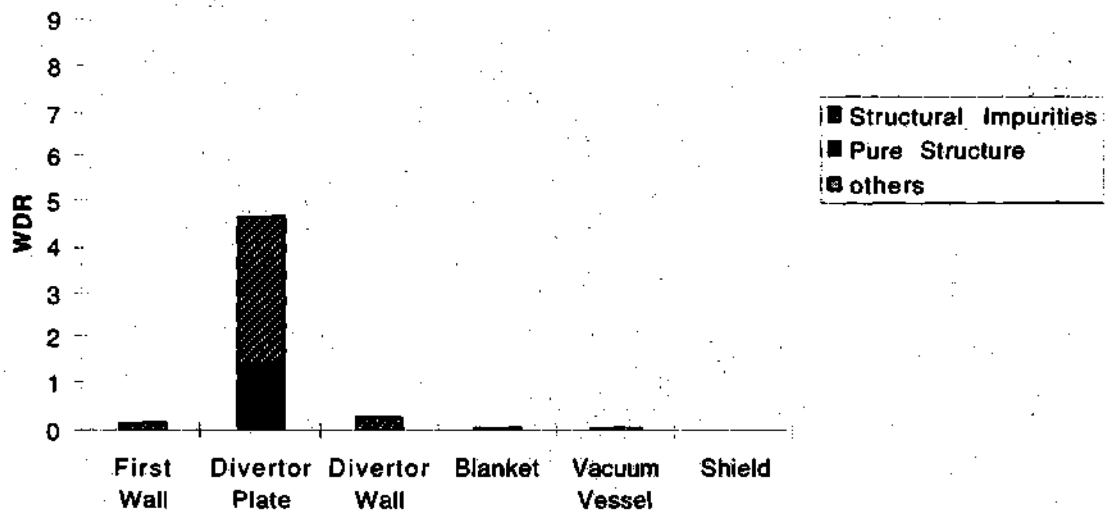

Figure VIII.3.a
Waste Disposal Rating
Reference V/Li Blanket Design (R3)

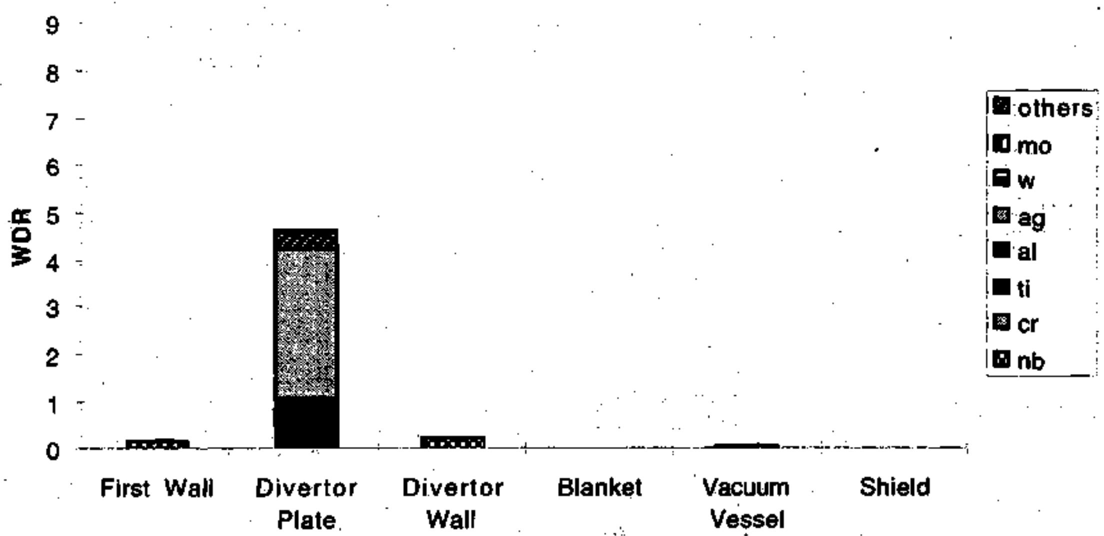

Figure VIII.3.b
Elemental Contributions to Structural Waste Disposal Rating
Reference V/Li Blanket Design (R3)

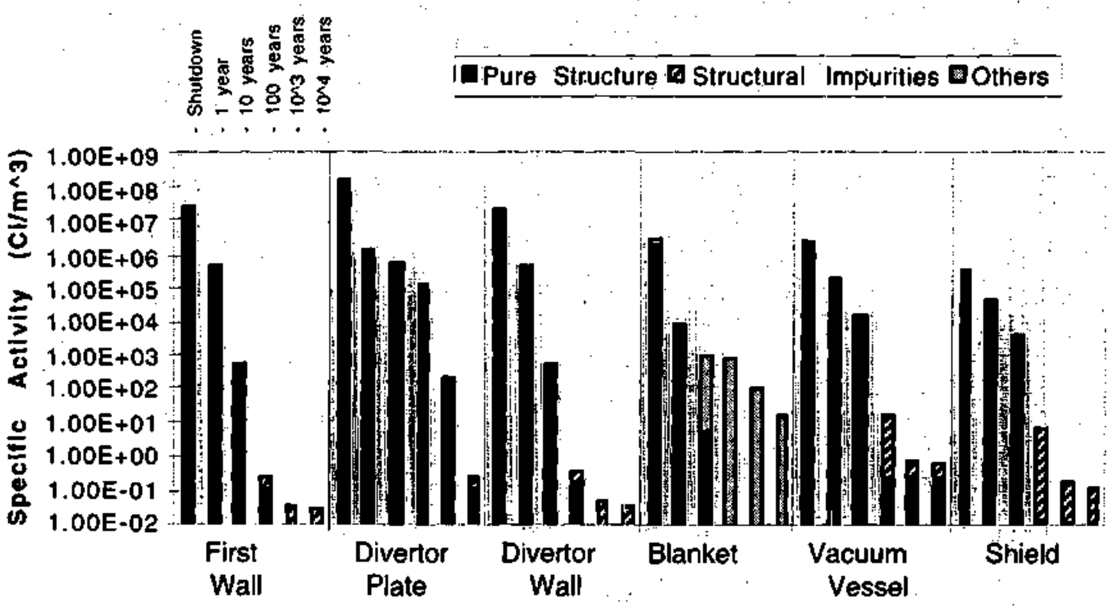

Figure VIII.3.c
Specific Activity
Reference V/Li Blanket Design (R3)

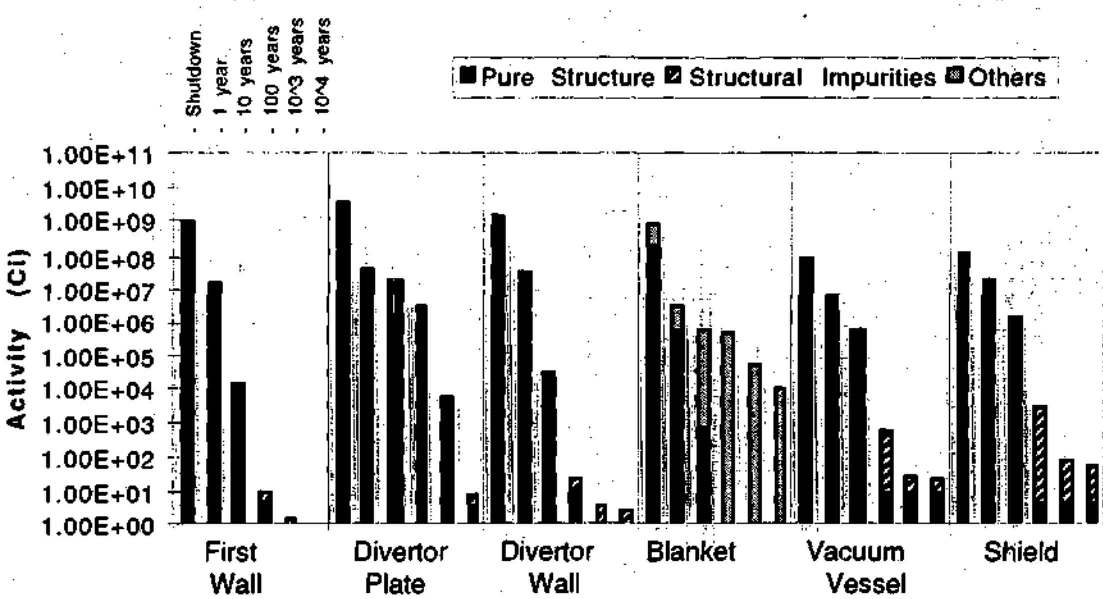

Figure VIII.3.d
Total Activity
Reference V/Li Blanket Design (R3)

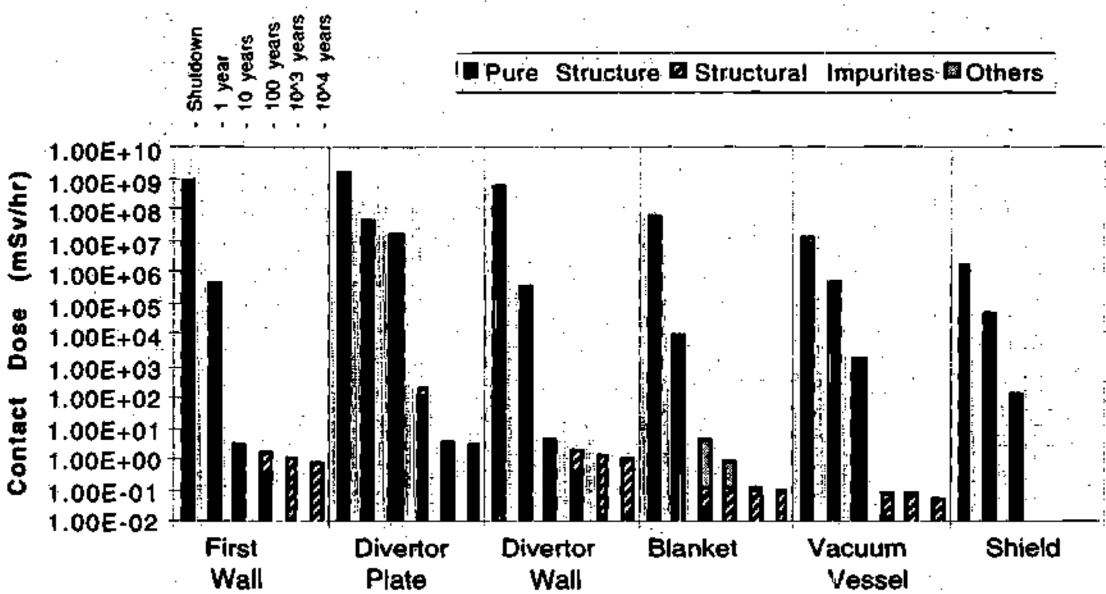

Figure VIII.3.e
Contact Dose
Reference V/Li Blanket Design (R3)

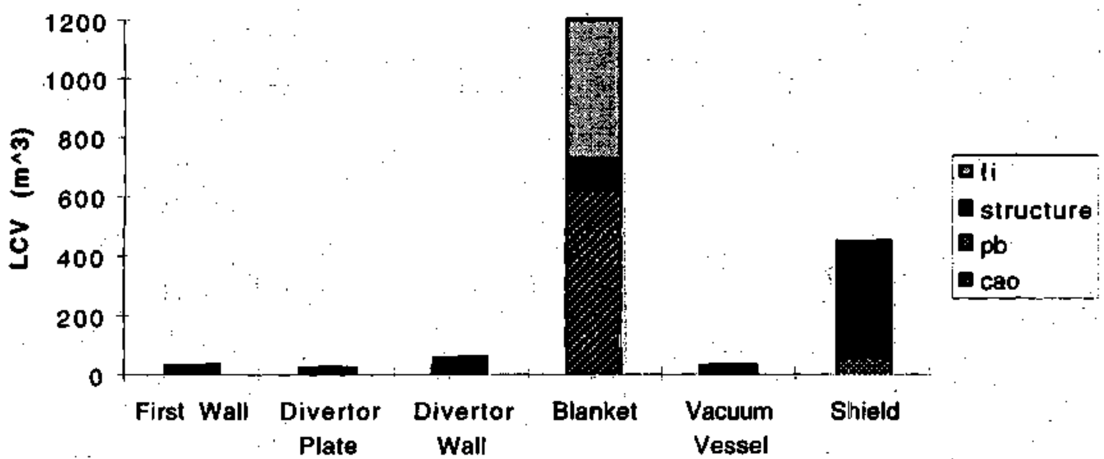

Figure VIII.3.f
Life Cycle Volume
Reference V/Li Blanket Design (R3)

VIII.D. DEMO with Reference SiC/Li_2ZrO_3/He Blanket Design (R4)

The structural material in the first wall, divertor wall, and blanket was silicon carbide (SiC). The structural material in the vacuum vessel and shield was the ferritic steel alloy given in table IV.2. The structural material in the divertor plate was dispersion strengthened copper. In figures VIII.4.a-VIII.4.e, "other" refers to lithium zirconate (Li_2ZrO_3), and beryllium (Be) in the blanket and lead (Pb) in the shield.

The waste disposal rating for the various components is shown in figure VIII.4.a. In this design, first wall, divertor wall, and divertor plate exceeded the WDR limit of unity. The WDR of the first wall was 1.56 and for the divertor wall, the WDR was 2.71. In the AIRIES-I report (5), a WDR of 0.12 was reported for the first wall using silicon carbide. Fetter (30) reports a limiting concentration of 30% for silicon in the first wall of a design irradiated to 20 MW-yr/m^2, which would correspond to a WDR=1.1[1]. The AIRIES-I report used the same limits as used in this analysis and an older version of the REAC code and associated cross sections (5). Fetter (37) used REAC*2 and associated cross sections. The difference between this analysis and Fetters, on the one hand, and the AIRIES results for the WDR of silicon carbide may be due to differences in the activation cross sections in successive versions of REAC.

1. Using Fetter's results $WDR = \frac{\rho_{SiC}\,Conc}{\rho_V\,Limit}$

ρ_{SiC} = density of silicon carbide = 2.50 g/cm^3; Conc = Weight Fraction Si = 28/(28+12)

ρ_V = density of Vanadium = 5.398 g/cm^3; Limit = Fetter's limit for Si = 30%

The blanket with the isotopically tailored zirconium, satisfies the WDR≤1 criterion. In the AIRIES-I report (5), they estimated the cost of isotopically tailoring the zirconium for the breeding material to be $2097/kg (5). Isotopically tailoring is necessary for the blanket to meet LLW criteria, but the cost would certainly be a factor in choosing this material.

The elemental contributions to the WDR in the structural materials in each region is shown in figure VIII.4.b. The contribution to the WDR was primarily from silicon. The impurities were insignificant for the WDR.

The divertor plate is the same as in the other designs and differences in activation are due to differences in the designs.

The specific activity for the various components is shown in figure VIII.4.c. Using the Japanese low-level waste (LLW) limit for solid wastes of 1 Ci/m^3 (29), the first wall will meet this criterion between 10 and 100 years after shutdown. The vacuum vessel and shield will not meet this criterion until after more than 100 years after shutdown, and all other components will not meet this criterion. The beryllium in the blanket will cause the blanket to not meet this criterion.

The total activity for each component is shown in figure VIII.4.d. For silicon, the decay was more rapid than for the iron-base alloys as shown by the large decrease in activity, but it does have a small component which has a long half-life.

The contact dose for each component is shown in figure VIII.4.e. Based on the IAEA proposal for a LLW limit for solid waste of <2 mSv/hr (29), the first wall, divertor wall, and divertor plate would not meet this criterion. The blanket would meet this criterion between 1 and 10 years after shutdown, and the vacuum vessel and shield between 10 and 100 years after shutdown.

The life cycle volume (LCV) for each component is shown in figure VIII.4.f. The volume is also given by material. In this design, a large neutron reflecting region made of primarily silicon carbide is used inside the vacuum vessel, which contributes to much larger waste volumes in the blanket region. Since the reflector is the same material as the structure, in figure VIII.4.f, it was included in the structure volume.

Based on the WDR criterion, silicon carbide should be close to qualifying for near-surface burial. The results of the AIRIES-I project (5) are more optimistic than this analysis or Fetter's (30) in this respect. The discrepancy needs to be resolved.

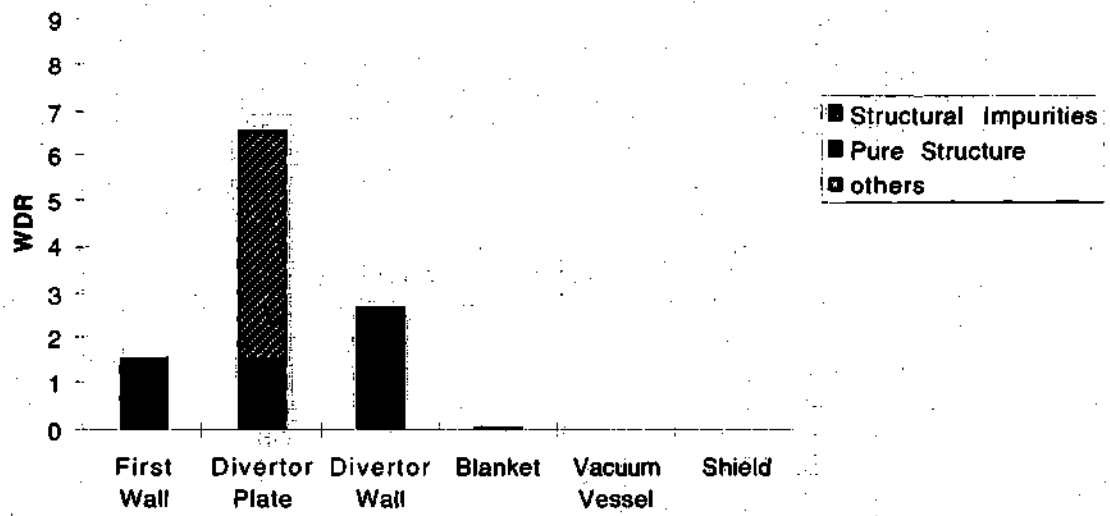

Figure VIII.4.a
Waste Disposal Rating
Reference $SiC/Li_2ZrO_3/He$ Blanket Design (R4)

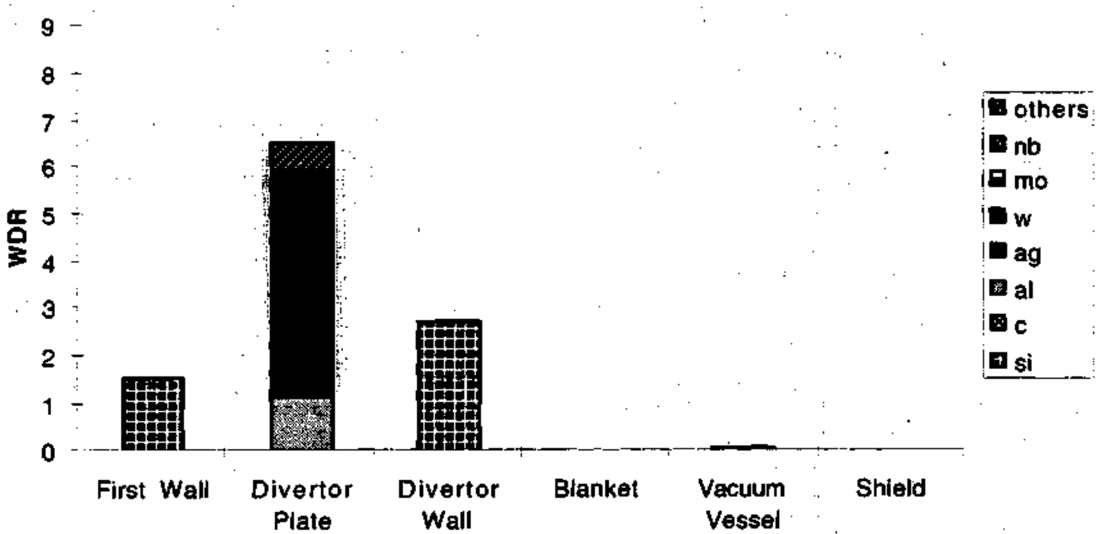

Figure VIII.4.b
Elemental Contributions to Structural Waste Disposal Rating
Reference $SiC/Li_2ZrO_3/He$ Blanket Design (R4)

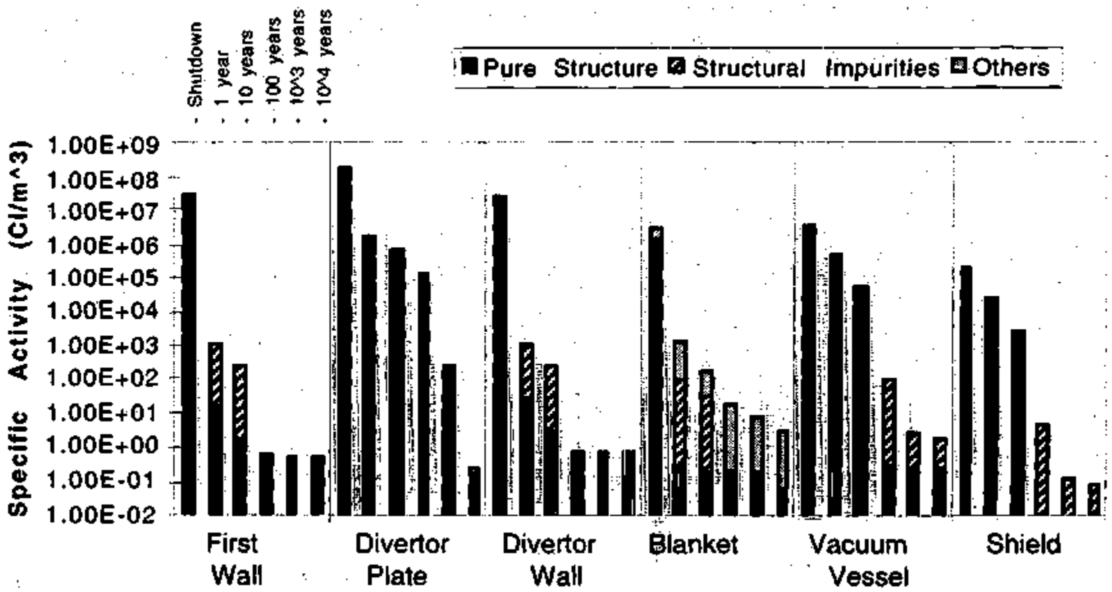

Figure VIII.4.c
Specific Activity
Reference $SiC/Li_2ZrO_3/He$ Blanket Design (R4)

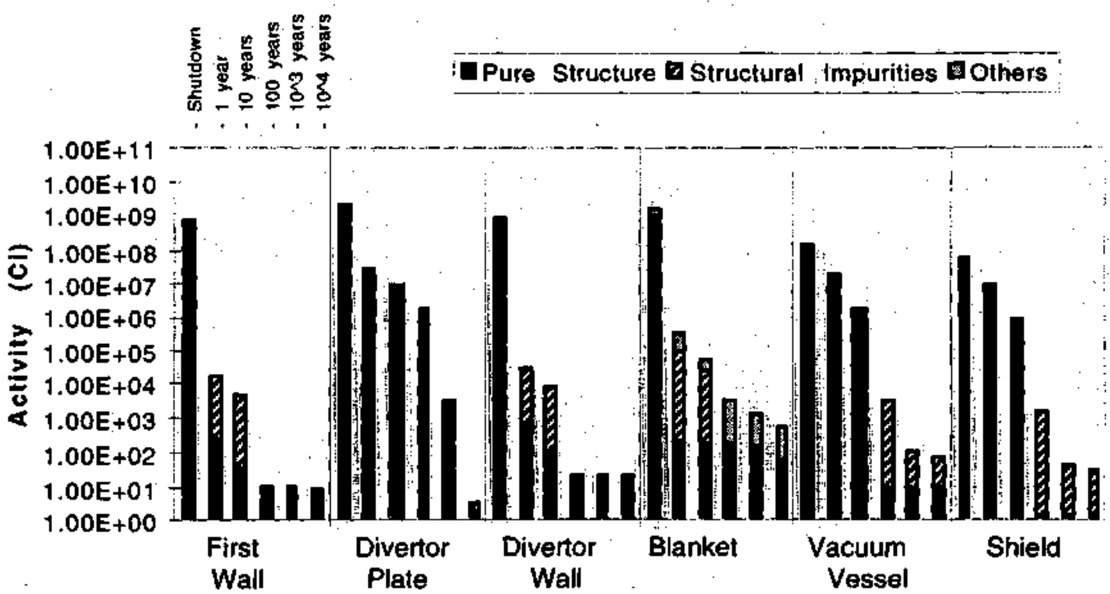

Figure VIII.4.d
Total Activity
Reference $SiC/Li_2ZrO_3/He$ Blanket Design (R4)

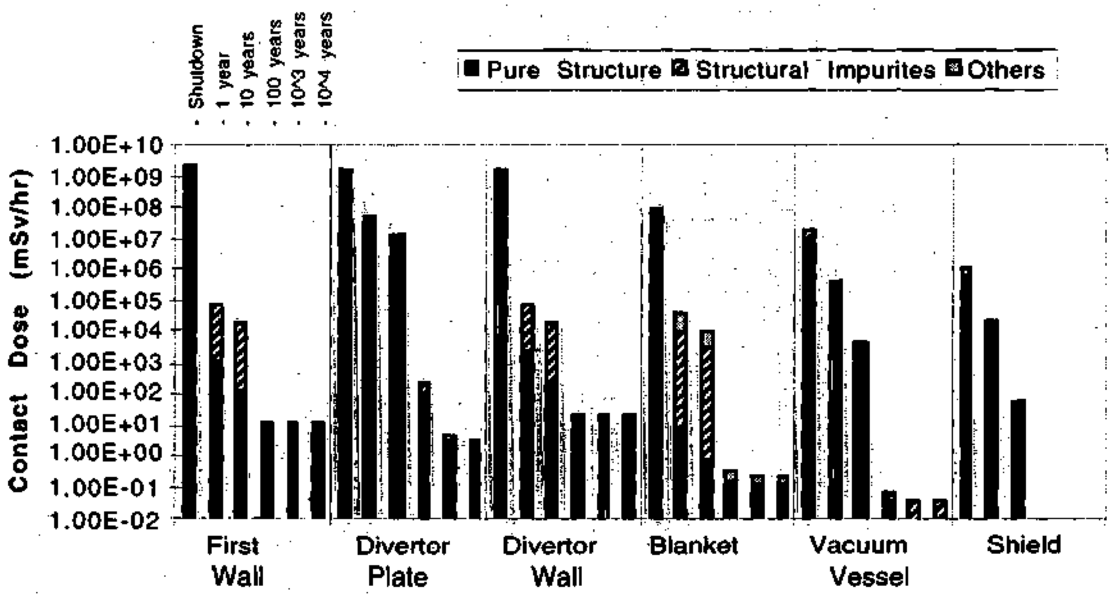

Figure VIII.4.e
Contact Dose
Reference SiC/Li_2ZrO_3/He Blanket Design (R4)

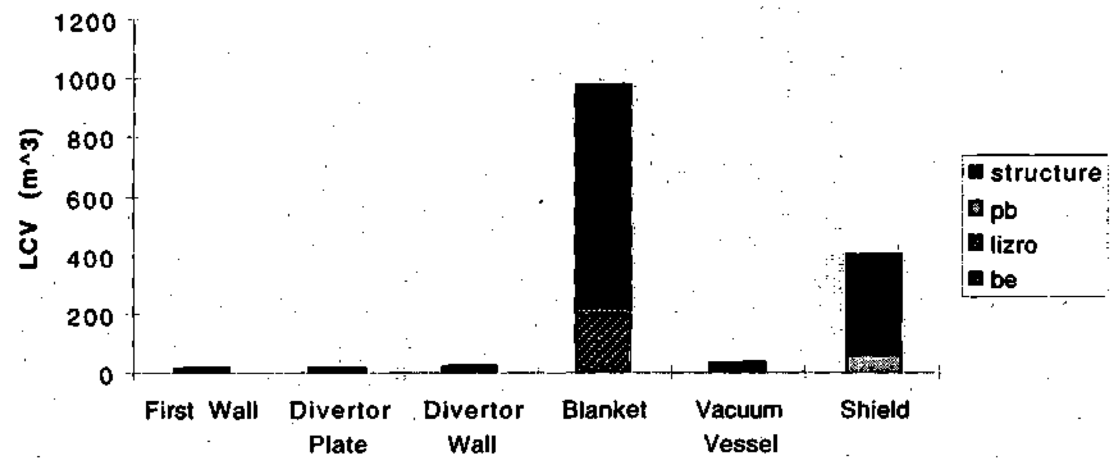

Figure VIII.4.f
Life Cycle Volume
Reference SiC/Li_2ZrO_3/He Blanket Design (R4)

VIII.E. DEMO with Variant $V/Li_2O/H_2O$ Blanket Design (V1)

A DEMO design similar to design R1 discussed in section VIII.A, except that V-4Cr-4Ti instead of ferritic steel, used as the structural material in the first wall, divertor wall, and blanket was considered. The structural material in the vacuum vessel and shield remained the ferritic steel alloy, because of the expense of vanadium. The structural material in the divertor plate was dispersion strengthened copper. In figures VIII.5.a-VIII.5.e, "other" refers to lithium oxide (Li_2O), and beryllium (Be) in the blanket and lead (Pb) in the shield.

The waste disposal rating for the various components is shown in figure VIII.5.a. In this design all components, except the divertor plate, will meet the WDR limit of unity.

The elemental contributions to the WDR in the structural materials in each region is shown in figure VIII.5.b. The contribution to the WDR of the primary alloying elements in vanadium is almost zero. An impurity level of 1 ppm Nb was assumed, which still meets the WDR limit, but the figure shows that impurity levels greater than this will begin to approach the WDR limit. The WDR of the blanket is 0.17, which is from the beryllium (WDR=0.08) and the lithium oxide (WDR=0.09) in the blanket.

The divertor plate is the same as in the other designs and differences in activation are due to differences in the designs.

The specific activity for the various components is shown in figure VIII.5.c. Using the Japanese LLW limit for solid wastes of 1 Ci/m^3 (29), the first wall and divertor wall would be classified as LLW between 10 and 100 years after shutdown. The blanket would not be classified as LLW because of the beryllium and lithium oxide. The vacuum vessel and shield would not meet this criterion because of the use of ferritic steel as a structural material. The total activity for each component is shown in figure VIII.5.d.

The contact dose for each component is shown in figure VIII.5.e. Using the IAEA proposal for a LLW limit for solid waste of <2 mSv/hr (29), the first wall and divertor wall would almost qualify as LLW between 1 and 10 years after shutdown. The blanket would be classified as LLW at 10 years after shutdown. All components would be classified as LLW using this criteria, except the common divertor plate and the divertor wall, which would still have a contact dose of 2.1 mSv/hr at 100 years after shutdown, only slightly greater than this criterion.

The life cycle volume (LCV) for each component is shown in figure VIII.5.f. The volume is also given by material. In this design, the volume of waste is lower than all other designs.

Replacement of the ferritic steel (FeS) by V-4Cr-4Ti (V) in the reference FeS/Li_2O/H_2O design leads to a design with attractive low activation properties in those components in which the replacement was made. If the replacement was also made in the divertor, all components would meet the WDR$\leq$1.0 criteria for near-surface burial.

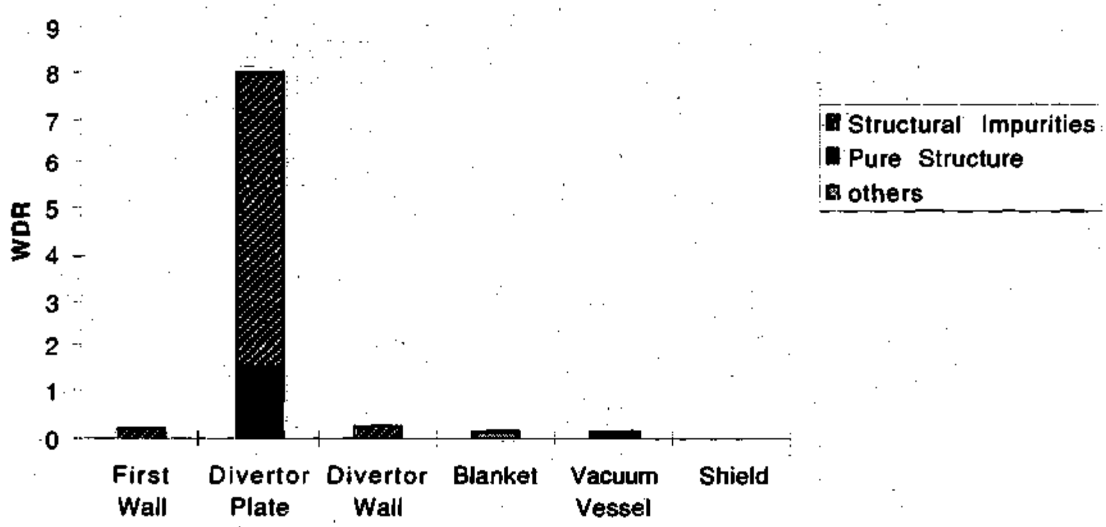

Figure VIII.5.a
Waste Disposal Rating
Variant $V/Li_2O/H_2O$ Blanket Design (V1)

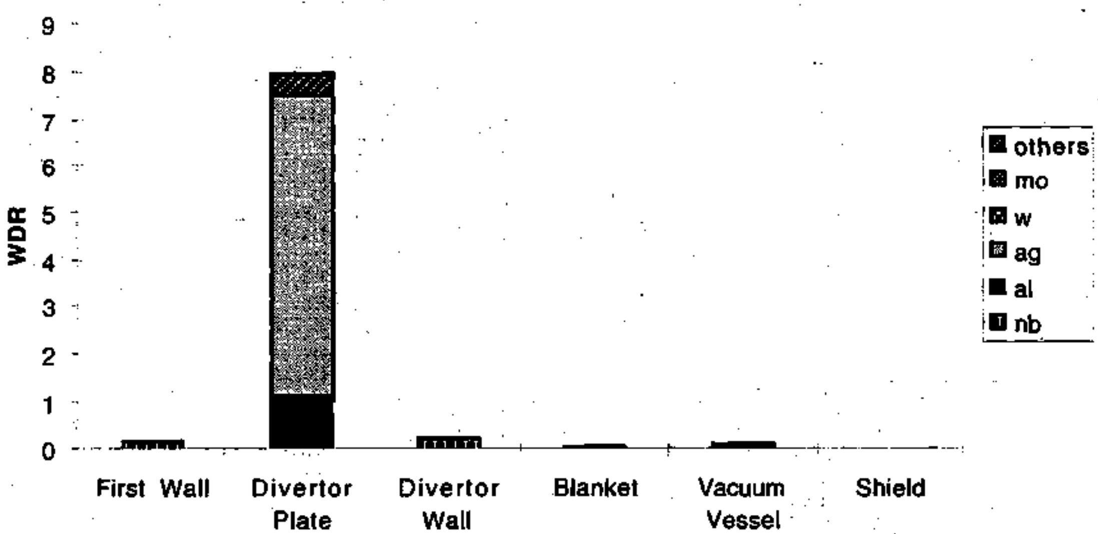

Figure VIII.5.b
Elemental Contributions to Structural Waste Disposal Rating
Variant $V/Li_2O/H_2O$ Blanket Design (V1)

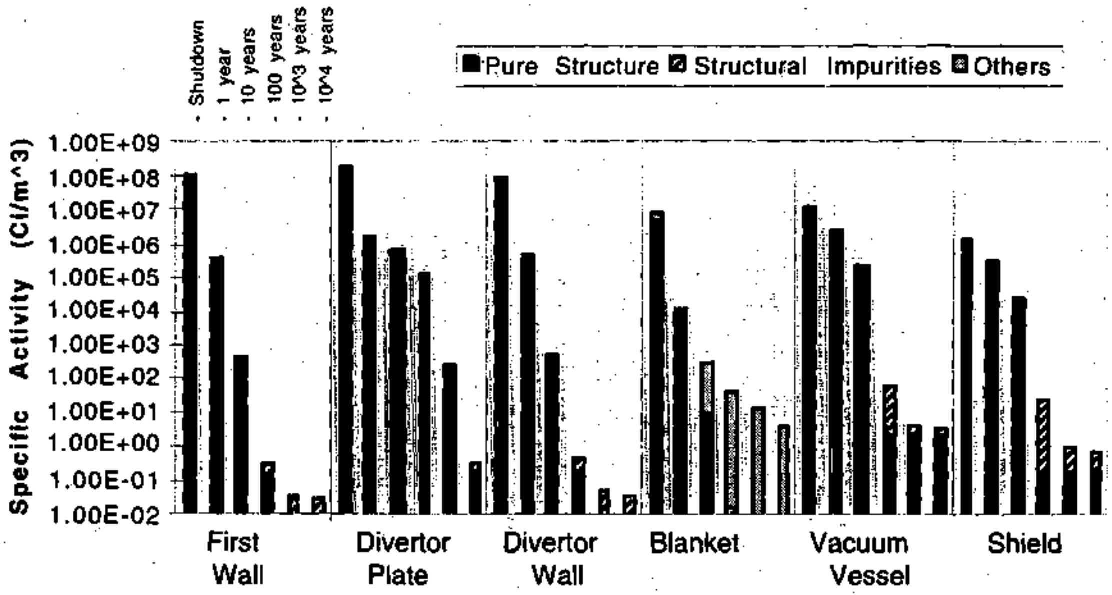

Figure VIII.5.c
Specific Activity
Variant $V/Li_2O/H_2O$ Blanket Design (V1)

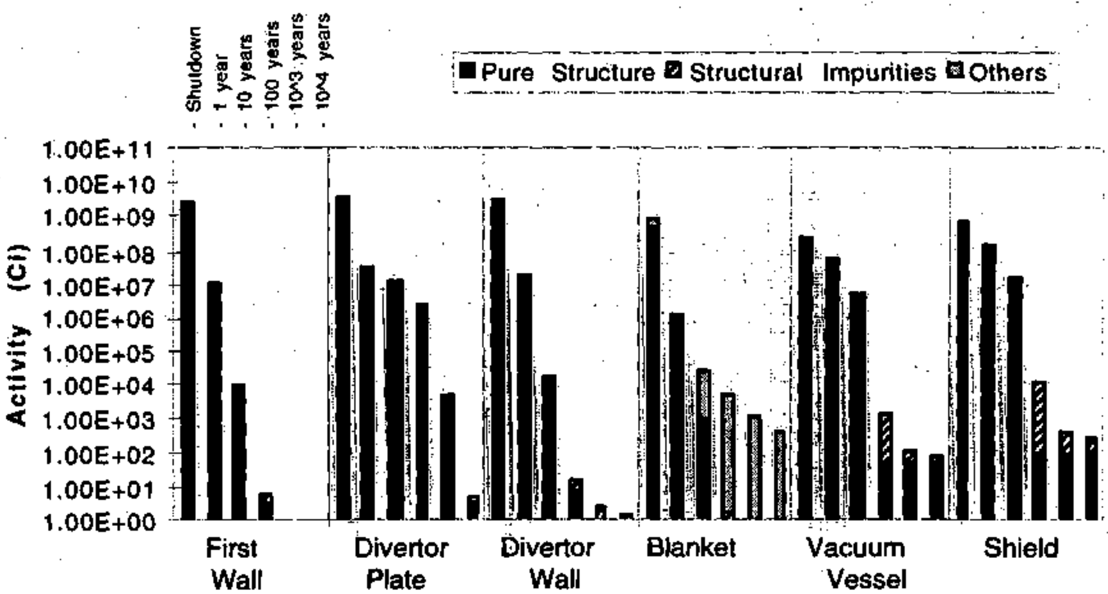

Figure VIII.5.d
Total Activity
Variant $V/Li_2O/H_2O$ Blanket Design (V1)

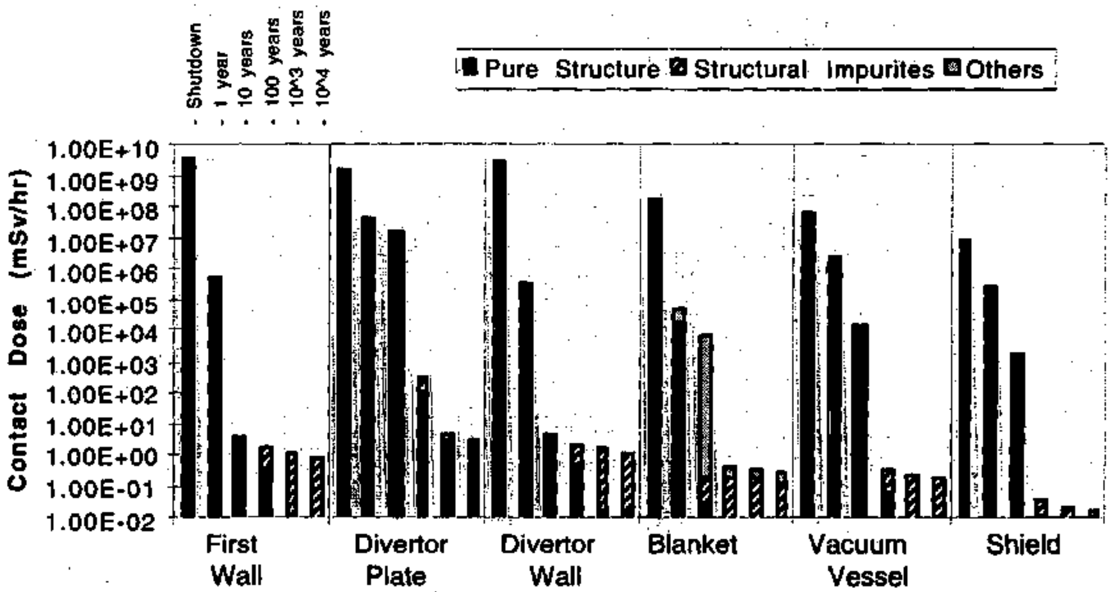

Figure VIII.5.e
Contact Dose
Variant $V/Li_2O/H_2O$ Blanket Design (V1)

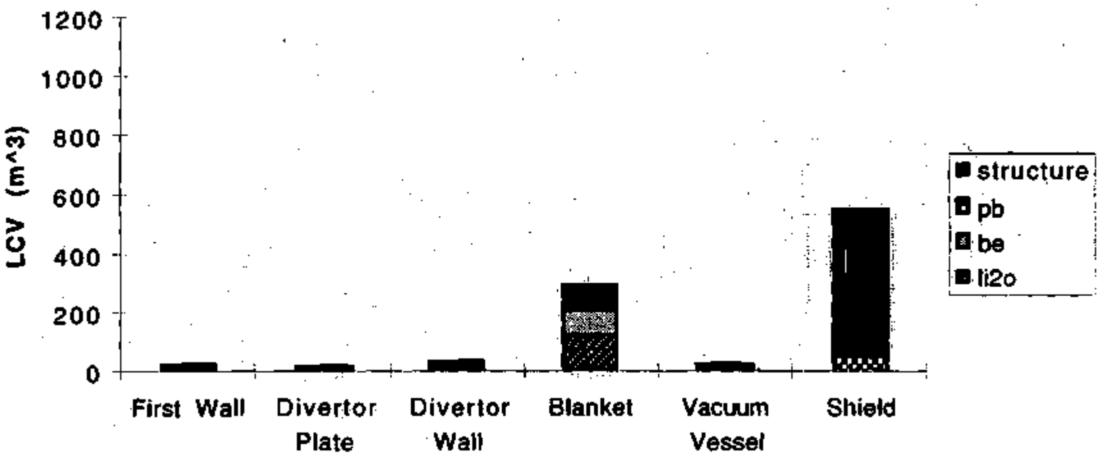

Figure VIII.5.f
Life Cycle Volume
Variant $V/Li_2O/H_2O$ Blanket Design (V1)

VIII.F. DEMOs with Variant
Austenitic Stainless Steel/Li_2O/H_2O Blanket Designs (V2,V3,V4)

Austenitic stainless steels have been widely used in industry and have an extensive database. Unless an advanced structural material, such as V-4Cr-4Ti, with low activation properties is successfully developed and tested by the time of construction, austenitic steel structure would have to be used. The existing materials of this type are all high activation and clearly not candidates for near-surface burial, even if irradiated to relatively low fluences. DEMO designs similar to design R1 discussed in section VIII.A, except that austenitic stainless steels (316SS, PCA, VA64) as structural materials instead of ferritic steel were used. The divertor plate was still dispersion strengthened copper. Figures VIII.6.a-VIII.6.f show the properties of the 316SS variant. The other austenitic materials, PCA and VA64, showed similar activation properties.

The waste disposal rating for the various components is shown in figure VIII.6.a. In these designs all components exceed the WDR limit of unity by orders of magnitude. This was true for all three austenitic materials considered. The activation of the base material was so high for these materials that impurities were not considered.

The elemental contributions to the WDR in the structural materials in each region is shown in figure VIII.6.b. The WDR for 316SS and PCA was nearly 100% from Mo, while for VA64, it was primarily from Mo and Nb.

The divertor plate is the same as in the other designs and differences in activation are due to differences in the designs.

The specific activity for the various components is shown in figure VIII.6.c. Using the Japanese LLW limit for solid wastes of 1 Ci/m^3 (29), all components would exceed the LLW limit by orders of magnitude. The specific activities are still quite high even after long decay times, in excess of 100 Ci/m^3 in the first wall for all three austenitic materials at 10,000 years after shutdown. The total activity for each component is shown in figure VIII.6.d.

The contact dose for each component is shown in figure VIII.6.e. Using the IAEA proposal for a LLW limit for solid waste of <2 mSv/hr (29), all components exceed this limit until 100 years or more after shutdown.

The life cycle volume (LCV) for each component is shown in figure VIII.6.f. The volume is also given by material. 316SS has the highest volume of any of these designs because of its poor thermo-mechanical properties and relative short lifetime. Both PCA and VA64 had less waste volume. VA64 had much less volume than either because of the much better thermo-mechanical properties and the resulting smaller plasma chamber, which reduces the volume of all material which surround it.

The austenitic stainless steels analyzed clearly would be classified as high-level waste and result in all of the difficulties associated with the requirement for deep geologic disposal.

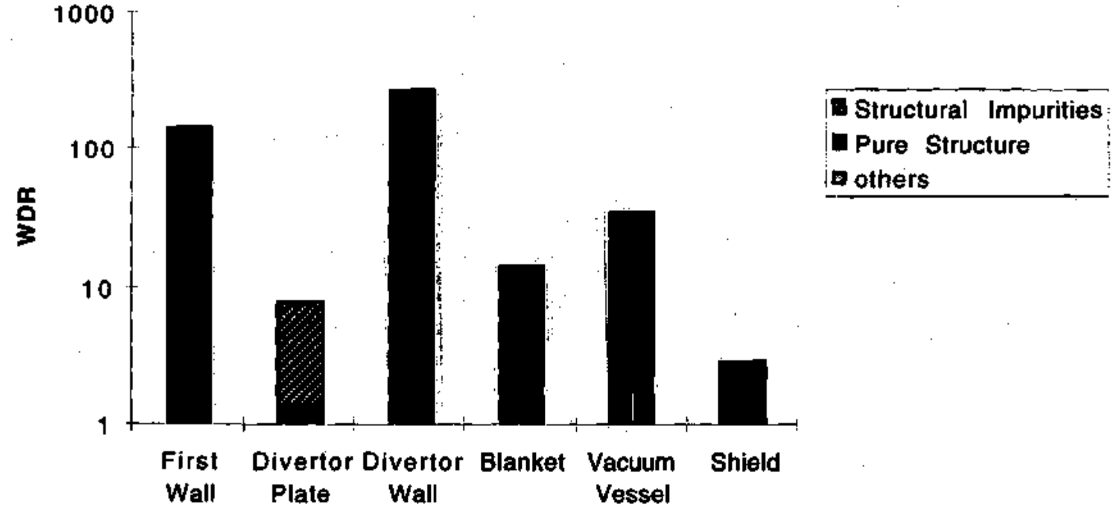

Figure VIII.6.a
Waste Disposal Rating
Variant 316SS/Li_2O/H_2O Blanket Design (V2)

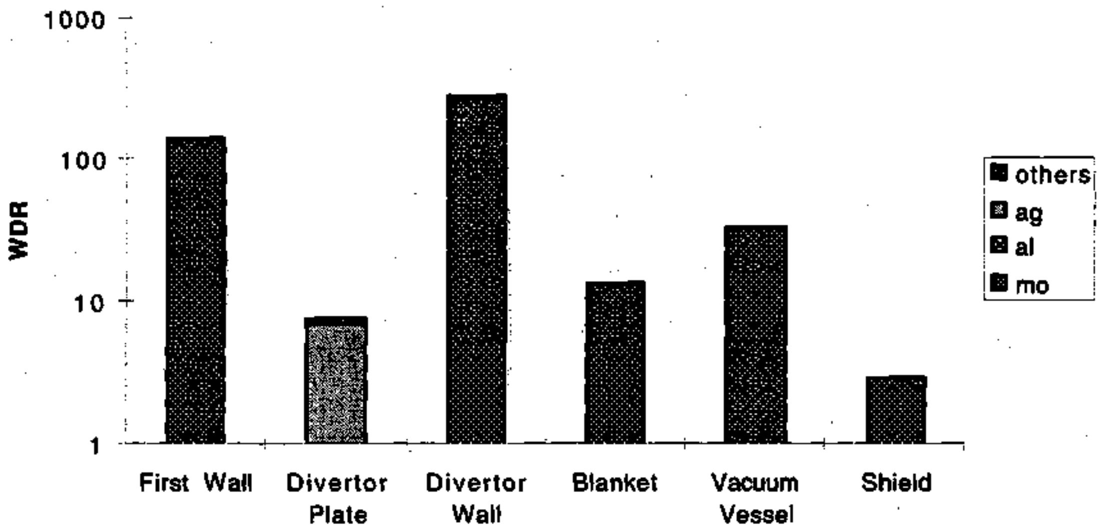

Figure VIII.6.b
Elemental Contributions to Structural Waste Disposal Rating
Variant 316SS/Li_2O/H_2O Blanket Design (V2)

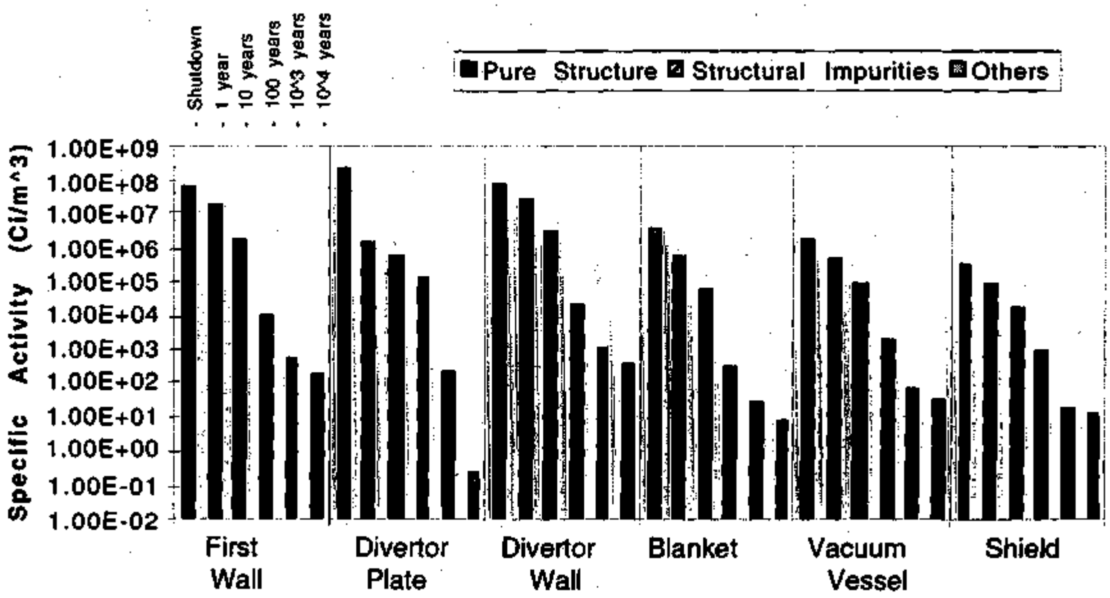

Figure VIII.6.c
Specific Activity
Variant 316SS/Li_2O/H_2O Blanket Design (V2)

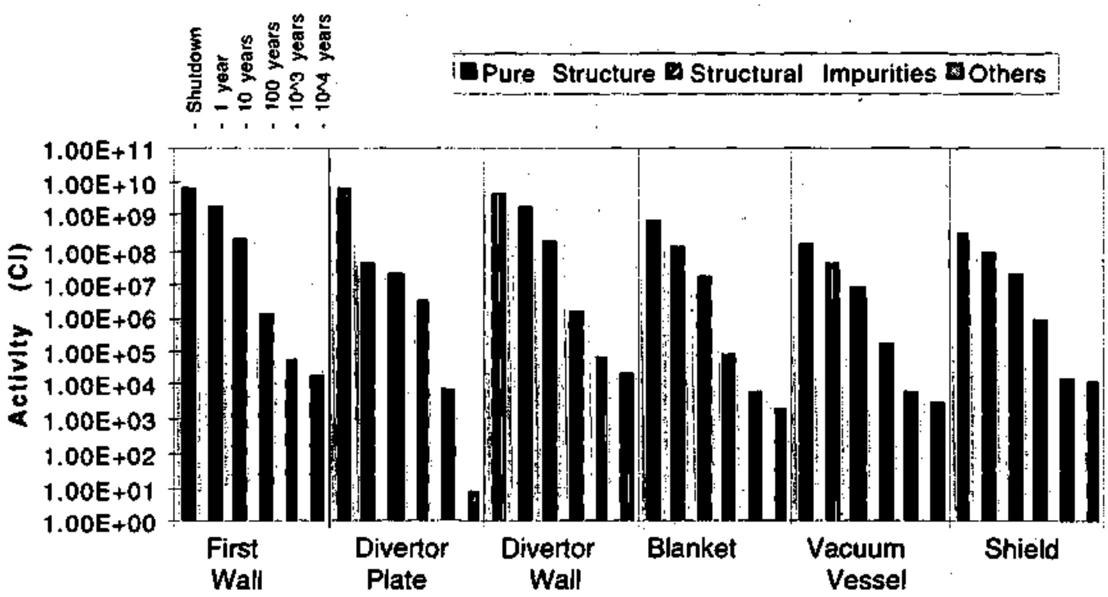

Figure VIII.6.d
Total Activity
Variant 316SS/Li_2O/H_2O Blanket Design (V2)

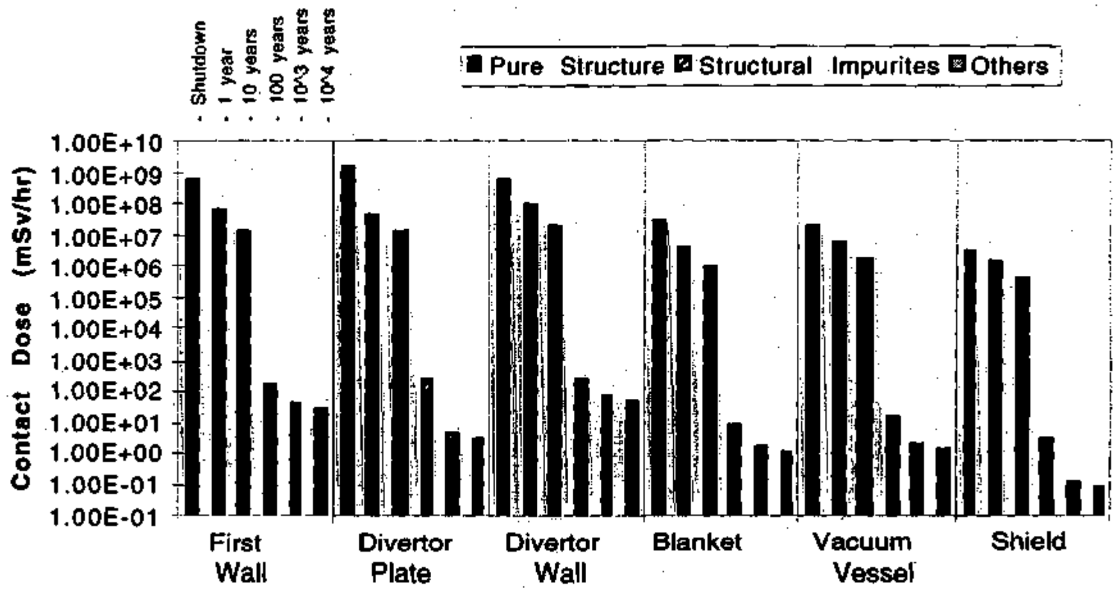

Figure VIII.6.e
Contact Dose
Variant 316SS/Li_2O/H_2O Blanket Design (V2)

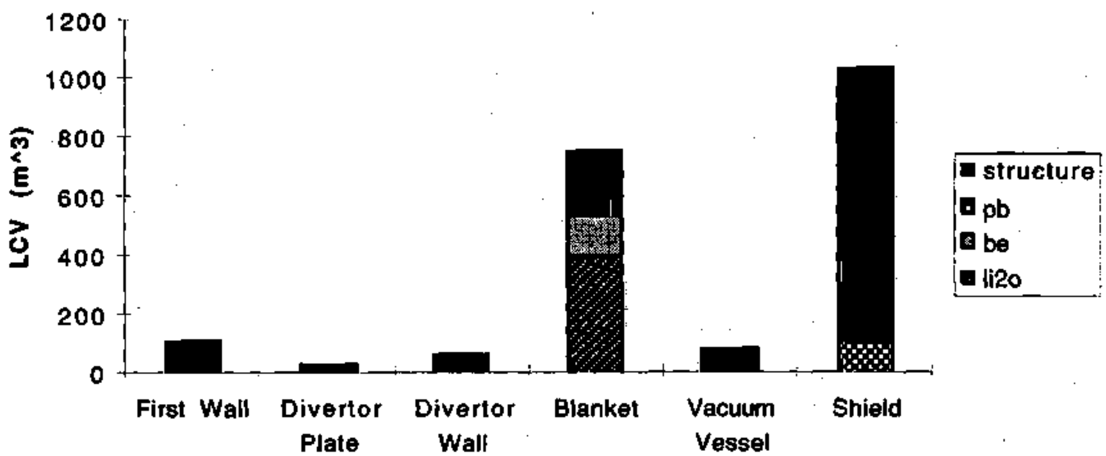

Figure VIII.6.f
Life Cycle Volume
Variant 316SS/Li_2O/H_2O Blanket Design (V2)

VIII.G. Comparison of Waste Disposal Parameters of Different DEMO Designs

Key waste disposal parameters for the various designs are compared in this section.

Waste Disposal Rating

The waste disposal rating (WDR), which is based on detailed analysis of the dose that could be received by an inadvertent intruder, is believed to be representative of a realistic criterion and is one of the key parameters evaluated in this study. The WDR limit for near-surface burial limit is unity. The results for the first wall, divertor wall, blanket, vacuum vessel and shield of each DEMO design are shown in figures VIII.7a-e, respectively. Figure VIII.7a-b shows that for either design R3 (V/Li) or design V1 ($V/Li_2O/H_2O$) using the vanadium alloy in the first wall and divertor wall will not have difficulties meeting near-surface burial criterion if impurities can be controlled to within plausible bounds. The ferritic steel without impurities will be below the WDR≤1 limit, but with the specified impurities ferritic steel slightly exceeded this limit in the divertor wall. The silicon carbide in the first wall and divertor wall was just above WDR≤1 limit. All other structural materials were not even close to meeting this limit in the first wall and divertor wall.

The WDR for the different blankets is shown in figure VIII.7.c. In the blankets incorporating the lower activation structural materials (V, SiC, and FeS), there will not be any difficulty meeting this limit. However, in SiC design the zirconium in the Li_2ZrO_3 breeder must be (expensively) isotopically tailored in order to meet the WDR≤1.

The WDR of the $MS/Li_{17}PB_{83}/H_2O$ blanket (R2) is noticeably higher than the other blankets. The WDR for each component is the volume weighted average of all solid materials within that component. In the blanket of design R2, the only solid material is the MANET structure, therefore, the WDR is solely due to the high activation MANET. In designs V2-V4, which incorporate the high activation austenitic steels, the WDR of the blanket is the volume weighted average of these high activation structural materials and the low activation breeder (Li_2O) and neutron multiplier (Be). If these high activation structural materials were to be used in the blanket, it would be necessary to separate the low activation materials (Li_2O, Be, etc.) from the high activation materials to reduce the total volume of material requiring deep geologic disposal.

The divertor plates for the different designs all used the same material, dispersion strengthened copper, the results were somewhat different for the different designs. This results from design differences and the resulting differences in neutron loads and irradiation times. The WDR without impurities tended to be slightly greater than unity and with impurities, it was considerably greater. Meeting this limit will be highly sensitive to impurities and the specific design, particularly neutron load and lifetime.

All lithium-bearing materials, without impurities, had WDR's much less than unity. Activation of elemental lithium does not pose any long-term disposal problems and the WDR is determined by alloying elements and impurities. With impurities included, the lithium lead was the only breeder which did not still meet near-surface burial limits.

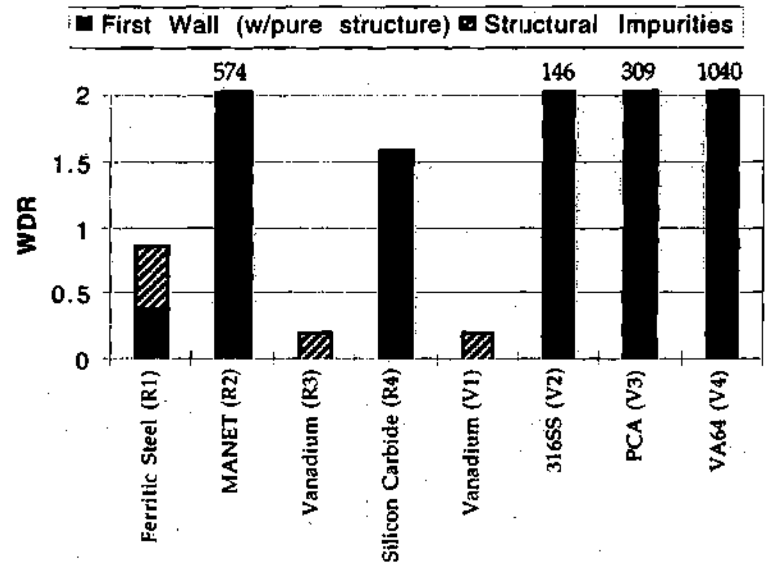

Figure VIII.7.a
Comparison of First Wall Waste Disposal Ratings

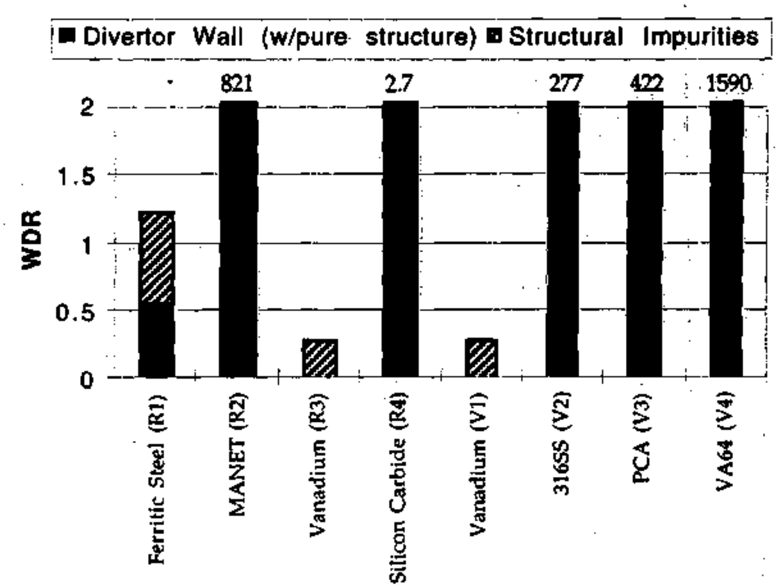

Figure VIII.7.b
Comparison of Divertor Wall Waste Disposal Ratings

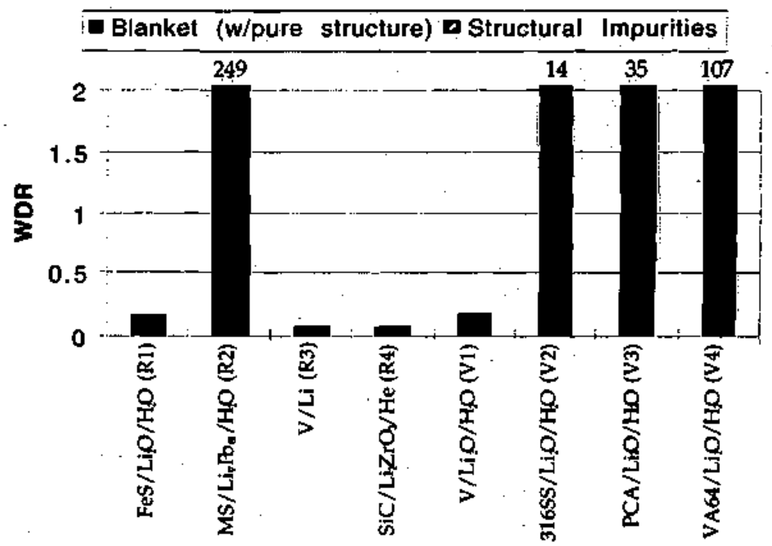

Figure VIII.7.c
Comparison of Blanket Waste Disposal Ratings

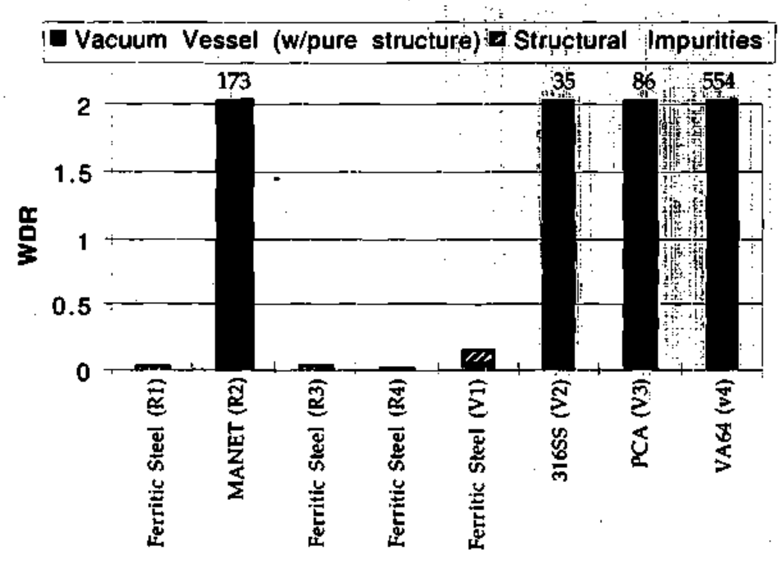

Figure VIII.7.d
Comparison of Vacuum Vessel Waste Disposal Ratings

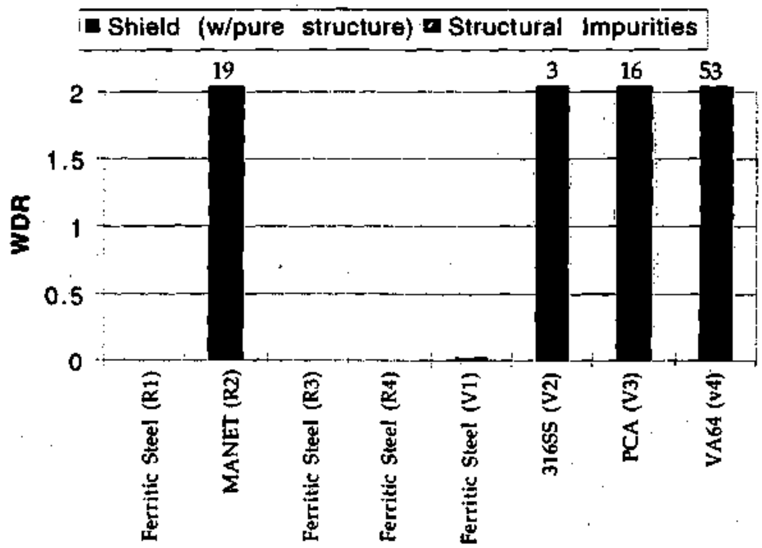

Figure VIII.7.e
Comparison of Shield Waste Disposal Ratings

Deep Disposal Index

Many of the components do not meet the near-surface burial limits, particularly with the levels of impurities considered. Figure VIII.8 shows the deep disposal index (DDI) for each of the designs, which is roughly a measure of the hazard posed by the high-level, WDR>1, waste from each design. The designs which incorporated the lower activation structural materials (i.e. V, FeS, SiC) had approximately 3 orders of magnitude lower DDI's than the other designs, and a large component of the DDI in the former was due to the dispersion-strengthened copper divertor plate.

For the V/Li reference design and the $V/Li_2O/H_2O$ variant design, the only component that did not meet WDR≤1 criterion and therefore contributes to the DDI was the common divertor plate. In the $SiC/Li_2ZrO_3/He$ reference design, the first wall and divertor wall WDR were slightly greater than 1.0 and therefore in addition to the divertor plate also contributed to the DDI for this design. In the $FeS/Li_2O/H_2O$ reference design, the divertor wall WDR was slightly greater than 1.0 and therefore in addition to the divertor plate also contributed to the DDI for this design. These three designs, because of the low WDR values and resulting low DDI's, pose less of a long term disposal hazard.

In all other designs (i.e. R2,V2,V3,V4), all components had WDR>1 and therefore contributed to the DDI. The first wall and divertor wall in most cases accounted for the bulk of the DDI because of their much higher WDR and only slightly smaller life cycle volumes than the remainder of the components.

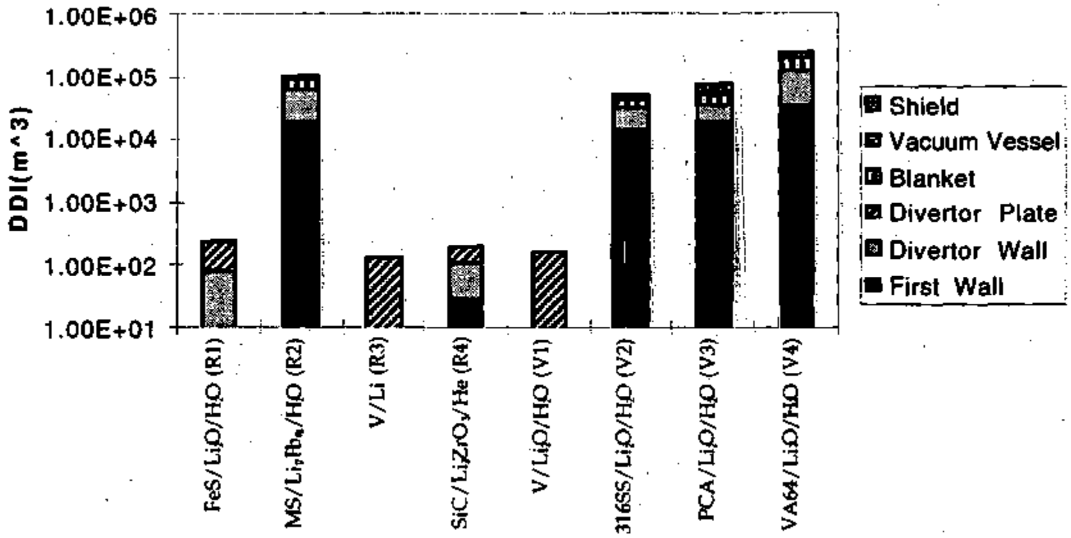

Figure VIII.8
Comparison of Deep Disposal Indexes

<u>Specific Activity</u>

For all first wall materials, the specific activiy was nearly the same at shutdown (~10^8 Ci/m^3). There was a very significant difference in the rate of decay for the specific activity in the different first wall materials. The specific activity at 10 years after shutdown for the different first walls is shown in figure VIII.9. This shows very large difference even at this moderate decay time.

Both vanadium and silicon carbide have specific activities, which have decayed by orders of magnitude at 10 years after shutdown. The impurities in silicon carbide dominated the specific activity at 10 years after shutdown and increased the specific activity by several orders of magnitude. With the impurities removed from the silicon carbide, the vanadium alloy has a much higher specific activity at 10 years after shutdown. The silicon carbide design (R4) with impurities removed comes close to meeting the Japanese <1 Ci/m^3 criterion for low level waste.

The common divertor plate material still has a very high specific activity (~2x10^8 Ci/m^3) at 10 years after shutdown in the different designs.

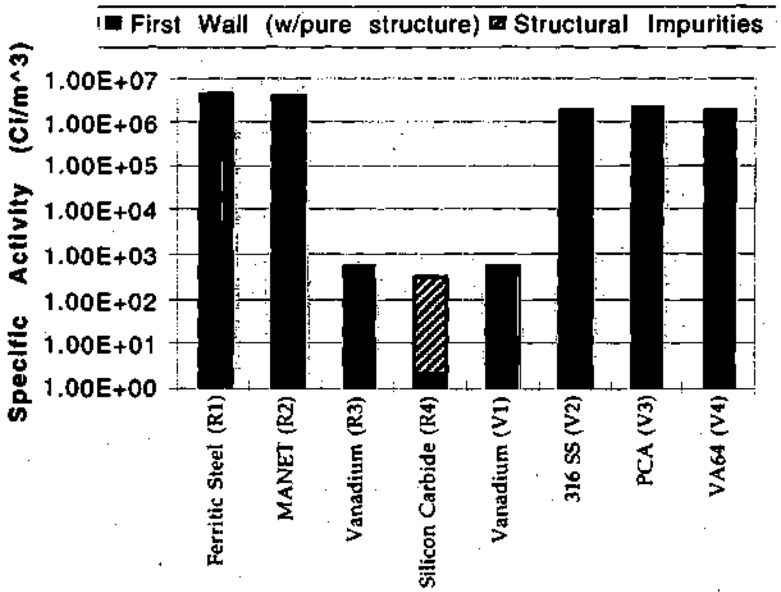

Figure VIII.9
Comparison of First Wall Specific Activities
(10 Years After Shutdown)

<u>Contact Dose</u>

For all first wall materials, the contact dose was nearly the same at shutdown (~10^9 mSv/hr). There was a very significant difference in the rate of decay for the contact dose in the different first wall materials. The contact dose at 10 years after shutdown for the different first walls is shown in figure VIII.10. This shows very large difference even at this moderate decay time.

Both vanadium and silicon carbide have contact doses, which have decayed by orders of magnitude at 10 years after shutdown. The impurities in silicon carbide dominated the contact dose at 10 years after shutdown and increased the contact dose by several orders of magnitude. The rapid decay of the contact dose in these materials will greatly reduce handling requirements assuming that the impurities can be controlled. Even with the impurities removed from the silicon carbide, the vanadium alloy still had a much lower contact dose at 10 years and in this regard is much better than any of the other materials. The vanadium designs (V3,R1) come close to meeting the IAEA <2mSv/hr criterion for low level waste.

The common divertor plate material still has a very high contact dose (~2×10^7 mSv/hr) at 10 years after shutdown in the various designs. This is primarily due to the reaction $^{63}Cu(n,\alpha)^{60}Co$. The 5.27 year half-life of Cobalt-60 will require a much longer decay time to reduce the contact dose to the same levels that vanadium and silicon carbide reached at 10 years.

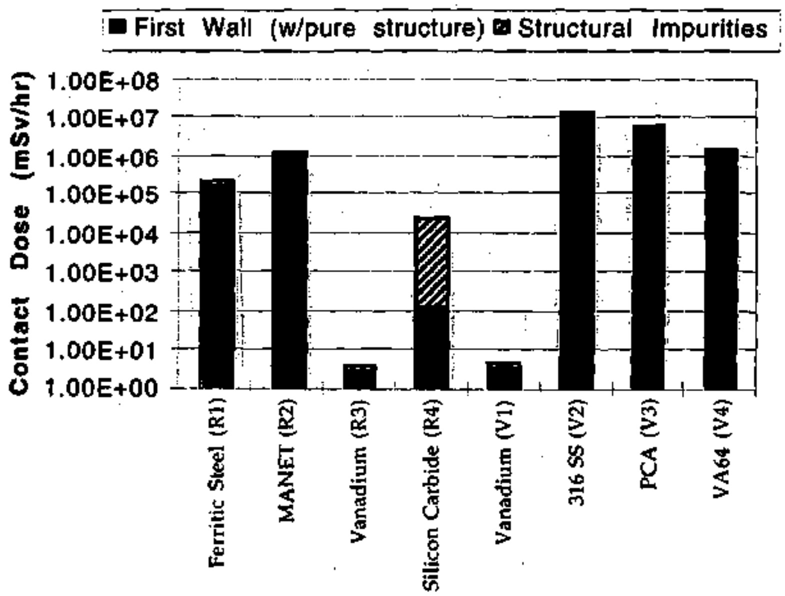

Figure VII.10
Comparison of First Wall Contact Doses
(10 Years After Shutdown)

Life Cycle Waste Volume

A comparison of the life cycle waste volume (LCV) for each design is shown in figure VIII.11. The difference between the smallest and largest was slightly more than a factor of two.

In the variant designs using 316SS and PCA, the shield volume was much larger than in the other designs. More shielding was not needed for these designs, but as a result of their relatively poor heat transfer properties, the heat and neutron loads must be reduced to meet thermal stress limits. This results in a larger plasma chamber, which increases the volume of all materials which surround the plasma chamber. The shield was most noticeably affected because it is furthest from the plasma.

The Argonne design (4) and the AIRIES-I (5) design both incorporate large neutron reflectors inside the vacuum vessel. In this model, the entire blanket/reflector region inside the vacuum vessel was replaced when the structure at the front of the blanket had reached its radiation damage limit. This caused the large blanket/reflector regions in the V/Li and SiC/Li_2ZrO_3/He reference designs to be replaced once each. Mori et al. (2), which was the basic reference for the FeS/Li_2O/H_2O reference design, incorporated a replaceable and a permanent blanket in their design. This was not done for any of the blankets in this analysis, but this clearly is a method to reduce the waste volume generated in the blanket. Even if this were to be done, the FeS/Li_2O/H_2O reference design R1 and the V/Li_20/H_2O variant design V1 would still generate considerably less waste volume than any of the other designs.

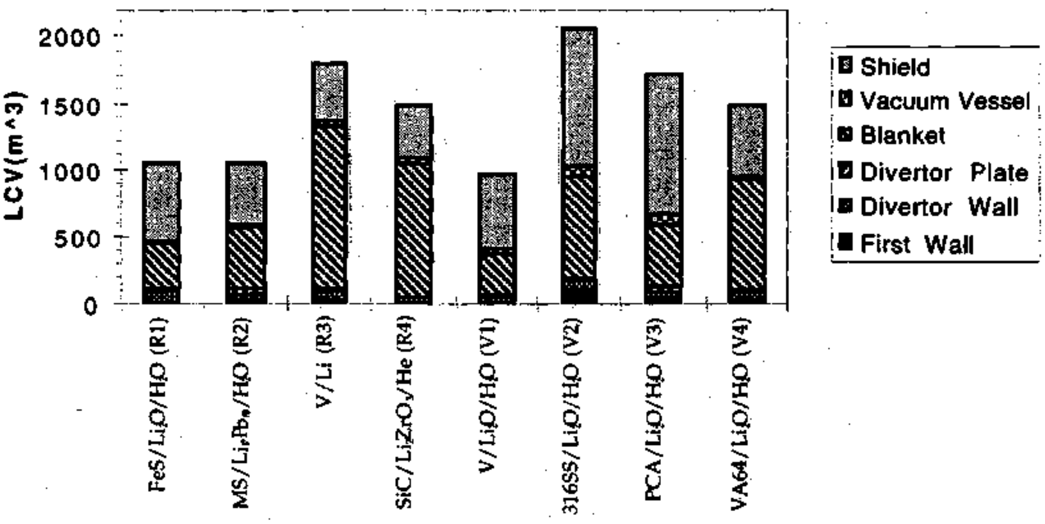

Figure VIII.11
Comparison of Life Cycle Volumes

CHAPTER IX

PARAMETER FITTING

Reactor designs may vary widely depending on the objectives of the design. Since these calculations are quite time consuming, it is desirable to perform a simple calculation to estimate the various activation parameters. In order to do this, the calculations has been performed for several flux (Φ) and fluence (Φt) values. The parameter was then fit using the least squares solution for the following equation.

$$\text{Parameter} = a\,\Phi + b\,(\Phi t)$$

Where the flux (Φ) is in n/cm^2-sec and the fluence (Φt) is n/cm^2.

The flux used was the flux calculated at the midpoint of the component. This value was used as the fitting parameter, since the thickness of the region may change, thereby changing the average flux seen in that region. The midpoint should be a reasonable value to be related to the average activation of the parameters throughout that component. In addition, it is a single value that is consistent for the goal of a simple method.

The results of the fitting were generally good with the calculated value generally within 10% of the actual value. The maximum difference is included with the results from the fit in appendix B. There are a few values which have errors greater than 50% and these were typically at the data points with the lowest magnitude which is expected for the least squares method.

The fit was performed for waste disposal rating and for specific activity and contact dose at 0, 1, 10, 10^2, 10^3, and 10^4 years after shutdown. The fitting for the first wall and divertor wall were combined because the two are modeled identically with the only difference being the flux and fluence seen by each. The results of the fitting are included in appendix B.

CHAPTER X

CONCLUSIONS

The waste disposal parameters for the four reference designs and the several variants of one of the designs were calculated. These results confirmed that the waste disposal parameters vary widely depending on the choice of materials. They consistently showed the overwhelming importance that impurities play in many of the parameters. It was also found that the various international criteria are by no means consistent and that one material may be well below near-surface burial limits, according to one criterion, while this same material clearly will not meet a different LLW criterion. We believe that Fetter 's (30) calculated disposal limits based on the USNRC disposal criterion (31) is the most realistic of the various criteria considered and this will be the basis for the conclusions.

It appears that it will be possible to develop a fusion reactor, that can meet near-surface burial, or low-level waste limits. The vanadium alloy, V-4Cr-4Ti, shows excellent promise in this regard. In the first wall and divertor wall, the pure vanadium alloy had a WDR that was nearly zero; while the pure ferritic steel had a WDR of approximately 0.5. Therefore, the allowable levels of impurities in the vanadium alloy will be roughly twice the allowable level of impurities in the ferritic steel. Since WDR>1 for silicon carbide in both the first wall and divertor wall, but not by large amounts, it may be possible to use this material with design modifications, but the acceptable levels of impurities will be very low because of the inherently higher WDR of the pure silicon carbide.

All lithium bearing materials used for breeding materials met the WDR≤1 criterion, with the exception of the impurities in the lithium lead. In regards to waste disposal characteristics, there were not any great differences between the different breeding materials, with the exception of the greater impurity levels specified in the lithium lead. Both the lithium lead and the lithium zirconate designs incorporated highly enriched lithium, which would be a factor in the cost. The lithium zirconate considered in this analysis was composed of isotopically tailored zirconium, which would greatly increase cost.

Both vanadium and silicon carbide designs will most likely use a different structural material for the vacuum vessel and shield, which must also be a low activation material. If a material such as 316SS where used, it would not meet near-surface burial criteria even if present in the shield. In this analysis, ferritic steel was used in the vacuum vessel and shields, which does meet does meet the WDR≤1 criterion in these components.

The divertor plate presents engineering difficulties because of the intense heat, radiation, and particle loads that it must withstand. Dispersion strengthened copper was assumed to be used for each design, since this is the divertor being developed for ITER. If this material is used, it will be necessary to give special consideration to the divertor design, if near-surface burial criteria are to be met. This could include reducing irradiation time or increasing the distance from the plasma, thereby lowering the neutron load by geometric attenuation, neither of which are desirable. The limiting element was the aluminum in the dispersion strengthener, alumina (Al_2O_3). The concentration of aluminum would need to be reduced by lowering the concentration of alumina, or substitution with another material, but it would still need to maintain acceptable thermo-mechanical properties.

MANET, which is being developed for DEMO in Europe, will clearly not be classified as LLW by any standards. This material uses molybdenum and niobium as alloying elements at the tenth of a percent level, but in order to meet the WDR≤1 criterion, these element must be present at the ppm level or lower.

The austenitic steels (316SS, PCA, VA64) analyzed would be used if an advanced material is not developed. These material all contain alloying elements that would cause them to require disposal as high-level waste. This could be a potential setback for the political acceptance of fusion as an environmental benign source of energy if the DEMO's produce large volumes of high-level radioactive waste.

A thermal insulating material had been required in the design by Mori et al. (2), and alumina was mention specifically. In design R1, the small amount of alumina included in this design was sufficient to cause the blanket to have a WDR>1. Since there are many possible materials that could be used, the alumina was not included in any subsequent results. However, this shows that even the small amount of material present in thermal insulators or coatings that may be required will need to be considered in this type of analysis and could easily cause the entire component to be classified as high level waste, if the proper materials are not used.

This analysis consistently showed that if fusion is to realize its potential as an environmentally benign energy source and avoid the long-term/deep repository waste disposal issue that is currently faced by fission reactors, the control of impurities to low levels will be necessary. In particular, a few specific impurities, such as Mo, Nb, and Ag, must be controlled to very low levels, if this is to be achieved.

APPENDIX A

ACTIVATION DATA

The following data in this appendix is the data calculated for each design. The data is tablulated for each parameter calculated for each design. The data is organized with a title specifying the parameter that is evaluated and the results for that parameter are then given by material in the component. The term structure refers to the structural material for that specific component and is not the same for all components. The term impurities refers to impurities in the structural material alone. For designs using a liquid breeder ($Li_{17}Pb_{83}$ or Li), the breeder was activated as a separated component and is included separately in the sections following the design in which it was used (A.3 and A.5).

In the first data set, the contribution of beryllium (be) present in the blanket to the waste disposal rating of the blanket is 5.72E-02. In the second data set, the contribution of tungsten (w) present in the structure of the first wall to the waste disposal rating of the first wall is 3.82E-01. In the third data set, the contribution of impurities in the structure of the shield to the specific activity at shutdown in the shield is 5.73+04 Ci/m^3. All data follows this format through out this appendix.

A.1. Reference $FeS/Li_2O/H_2O$ Design (R1)

Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	7.00E-02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.54E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	5.75E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.27E-05
structure	3.86E-01	1.47E+00	5.46E-01	1.32E-02	8.65E-03	7.81E-04
impurities	4.82E-01	6.23E+00	6.69E-01	2.87E-02	3.49E-02	3.42E-03

Structure Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
w	3.82E-01	0.00E+00	5.38E-01	1.32E-02	8.65E-03	7.80E-04
mo	7.91E-02	0.00E+00	1.04E-01	7.31E-03	9.48E-03	8.39E-04
nb	1.33E-01	0.00E+00	1.79E-01	1.49E-02	2.17E-02	1.93E-03
al	2.58E-01	1.08E+00	3.70E-01	6.06E-03	2.67E-03	2.25E-04
ag	0.00E+00	5.92E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
others	1.56E-02	7.03E-01	2.44E-02	3.91E-04	1.07E-03	4.34E-04

Specific Activity w/o Tritium (Ci/m^3) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.86E+05	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	5.45E+05	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.14E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.97E+00
structure	1.42E+08	2.12E+08	1.20E+08	4.26E+06	3.21E+06	5.55E+05
impurities	4.77E+06	1.86E+05	3.55E+06	1.85E+05	2.42E+05	5.73E+04

Specific Activity w/o Tritium (Ci/m^3) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.91E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.63E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.80E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.67E-02
structure	5.39E+07	1.73E+06	5.06E+07	1.34E+06	7.22E+05	1.08E+05
impurities	4.40E+05	7.58E+03	3.39E+05	1.01E+04	4.18E+03	3.68E+02

Specific Activity w/o Tritium (Ci/m^3) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.57E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.26E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.21E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.93E-04
structure	5.13E+06	6.75E+05	4.84E+06	1.23E+05	6.49E+04	1.00E+04
impurities	3.16E+03	4.17E+02	3.95E+03	8.00E+01	8.07E+01	2.42E+01

Specific Activity w/o Tritium (Ci/m^3) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.96E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	8.43E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.82E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-04
structure	2.20E+01	1.32E+05	3.09E+01	7.37E-01	4.57E-01	4.00E-02
impurities	3.08E+02	0.00E+00	4.26E+02	8.41E+00	2.78E+01	1.17E+01

Specific Activity w/o Tritium (Ci/m^3) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.64E+00	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	7.89E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.42E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.50E-06
structure	2.19E+01	2.59E+02	3.08E+01	7.34E-01	4.56E-01	3.97E-02
impurities	8.61E+00	1.02E-01	1.16E+01	3.18E-01	8.58E-01	3.17E-01

Specific Activity w/o Tritium (Ci/m^3) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.72E-01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.74E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.15E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.69E-06
structure	2.15E+01	1.45E-01	3.01E+01	7.18E-01	4.45E-01	3.90E-02
impurities	5.06E+00	1.43E-01	6.65E+00	1.85E-01	5.44E-01	2.06E-01

Total Activity w/o Tritium (Ci) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	9.11E+07	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	9.54E+06	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.39E+08	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E+02
structure	3.58E+09	4.36E+09	8.22E+09	4.03E+08	8.60E+07	2.77E+08
impurities	1.21E+08	3.82E+06	2.43E+08	1.75E+07	6.48E+06	2.86E+07

Total Activity w/o Tritium (Ci) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.58E+04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.86E+02	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.17E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E+00
structure	1.36E+09	3.55E+07	3.46E+09	1.27E+08	1.94E+07	5.39E+07
impurities	1.11E+07	1.56E+05	2.32E+07	9.57E+05	1.12E+05	1.84E+05

Total Activity w/o Tritium (Ci) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.69E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.95E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.44E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.22E-02
structure	1.30E+08	1.39E+07	3.31E+08	1.16E+07	1.74E+06	5.01E+06
impurities	8.00E+04	8.56E+03	2.70E+05	7.57E+03	2.16E+03	1.21E+04

Total Activity w/o Tritium (Ci) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.67E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.48E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.18E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.65E-03
structure	5.57E+02	2.71E+06	2.11E+03	6.97E+01	1.22E+01	2.00E+01
impurities	7.80E+03	0.00E+00	2.91E+04	7.96E+02	7.46E+02	5.84E+03

Total Activity w/o Tritium (Ci) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.82E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.38E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	5.48E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.24E-04
structure	5.55E+02	5.33E+03	2.11E+03	6.95E+01	1.22E+01	1.98E+01
impurities	2.18E+02	2.09E+00	7.97E+02	3.01E+01	2.30E+01	1.58E+02

Total Activity w/o Tritium (Ci) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.26E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	8.30E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.05E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.78E-04
structure	5.43E+02	2.97E+00	2.06E+03	6.80E+01	1.19E+01	1.95E+01
impurities	1.28E+02	2.94E+00	4.55E+02	1.75E+01	1.46E+01	1.03E+02

Contact Dose (mSv/hr) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.54E+07	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.21E+07	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	4.51E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E+01
structure	8.15E+08	1.62E+09	6.63E+08	2.62E+07	1.78E+07	2.60E+06
impurities	9.97E+07	1.60E+06	7.39E+07	3.55E+06	5.73E+06	1.66E+06

Contact Dose (mSv/hr) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	7.21E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	5.02E+02	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.84E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E+00
structure	3.87E+07	4.84E+07	3.42E+07	1.51E+06	1.06E+06	1.27E+05
impurities	4.70E+06	1.86E+05	3.58E+06	1.11E+05	2.63E+05	3.85E+03

Contact Dose (mSv/hr) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	5.03E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	5.72E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	4.23E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.17E-03
structure	1.49E+05	1.47E+07	2.36E+05	4.21E+03	2.10E+03	3.30E+02
impurities	5.33E+04	2.00E+02	5.93E+04	1.88E+03	9.98E+02	8.47E+01

Contact Dose (mSv/hr) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.79E-03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.27E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.20E-01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.42E-03
structure	1.07E+00	1.10E+02	1.86E+00	2.71E-02	1.33E-02	2.21E-03
impurities	1.89E+00	2.08E+02	2.54E+00	9.96E-02	1.10E-01	9.68E-03

Contact Dose (mSv/hr) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.64E-03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.27E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.86E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-05
structure	5.05E-02	3.60E+00	7.54E-02	1.39E-03	8.39E-04	7.34E-05
impurities	1.50E+00	1.71E+00	2.10E+00	8.43E-02	9.99E-02	8.85E-03

Contact Dose (mSv/hr) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.63E-03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.26E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.69E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.12E-06
structure	4.92E-02	3.57E+00	7.31E-02	1.36E-03	8.13E-04	7.27E-05
impurities	1.34E+00	1.41E-01	1.88E+00	6.75E-02	7.59E-02	6.71E-03

Life Cycle Waste Volume (m^3)

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.87E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.75E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	6.51E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.65E+01
structure	2.53E+01	2.05E+01	6.84E+01	9.47E+01	2.68E+01	4.99E+02

Deep Disposal Index
2.41E+02

A.2. Reference MS/$Li_{17}Pb_{83}$/H_2O Design (R2)

Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-04
structure	5.74E+02	1.61E+00	8.21E+02	2.49E+02	1.73E+02	1.89E+01
impurities	0.00E+00	5.64E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Structure Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
mo	1.49E+02	0.00E+00	2.12E+02	5.34E+01	3.54E+01	3.76E+00
nb	4.24E+02	0.00E+00	6.10E+02	1.96E+02	1.38E+02	1.52E+01
al	0.00E+00	1.20E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ag	0.00E+00	5.43E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
others	8.79E-01	6.23E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.88E+00
structure	1.14E+08	2.02E+08	1.01E+08	1.15E+07	2.88E+06	7.41E+05
impurities	0.00E+00	1.91E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-01
structure	5.06E+07	1.80E+06	4.95E+07	4.86E+06	7.97E+05	1.97E+05
impurities	0.00E+00	6.57E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.70E-04
structure	4.77E+06	7.02E+05	4.74E+06	4.64E+05	8.59E+04	2.16E+04
impurities	0.00E+00	2.77E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.25E-04
structure	2.42E+03	1.37E+05	3.54E+03	4.56E+02	7.74E+02	2.86E+02
impurities	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-05
structure	5.61E+02	2.70E+02	8.39E+02	1.22E+02	6.78E+01	1.08E+01
impurities	0.00E+00	1.08E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.46E-06
structure	1.27E+02	1.67E-01	1.84E+02	4.42E+01	3.65E+01	6.86E+00
impurities	0.00E+00	1.53E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45E+02
structure	3.92E+09	4.69E+09	5.09E+09	1.58E+09	5.44E+07	3.02E+08
impurities	0.00E+00	4.42E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.96E+00
structure	1.74E+09	4.15E+07	2.49E+09	6.66E+08	1.51E+07	8.05E+07
impurities	0.00E+00	1.52E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.38E-02
structure	1.64E+08	1.62E+07	2.38E+08	6.36E+07	1.62E+06	8.81E+06
impurities	0.00E+00	6.41E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.13E-02
structure	8.33E+04	3.17E+06	1.78E+05	6.24E+04	1.46E+04	1.17E+05
impurities	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.56E-04
structure	1.93E+04	6.24E+03	4.21E+04	1.67E+04	1.28E+03	4.39E+03
impurities	0.00E+00	2.50E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.77E-04
structure	4.37E+03	3.86E+00	9.21E+03	6.05E+03	6.89E+02	2.80E+03
impurities	0.00E+00	3.53E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.49E+01
structure	9.11E+08	1.69E+09	7.18E+08	9.67E+07	3.14E+07	9.52E+06
impurities	0.00E+00	1.59E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.47E+00
structure	4.74E+07	5.03E+07	4.18E+07	5.56E+06	1.40E+06	2.77E+05
impurities	0.00E+00	1.56E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.73E-03
structure	1.31E+06	1.52E+07	1.53E+06	3.06E+05	3.35E+05	7.52E+04
impurities	0.00E+00	7.00E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.93E-03
structure	1.94E+03	1.14E+02	2.79E+03	8.80E+02	6.22E+02	6.89E+01
impurities	0.00E+00	1.91E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.93E-05
structure	1.87E+03	4.00E+00	2.68E+03	8.50E+02	6.01E+02	6.63E+01
impurities	0.00E+00	1.56E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.96E-06
structure	1.37E+03	3.97E+00	1.97E+03	6.25E+02	4.42E+02	4.87E+01
impurities	0.00E+00	1.22E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Life Cycle Waste Volume (m^3)

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E+01
structure	3.44E+01	2.31E+01	5.02E+01	1.37E+02	1.89E+01	4.08E+02

Deep Disposal Index
1.07E+05

A.3. Liquid Breeder for Design R2 - $Li_{17}Pb_{83}$

Waste Disposal Rating

lipb	6.64E-02
impurities	3.95E+00

Breeder Waste Disposal Rating

mo	3.46E-01
ag	3.56E+00
al	1.33E-02
others	1.03E-01

Specific Activity w/o Tritium (Ci/m^3)

@	lipb	impurities
Shutdown	1.22E+07	4.92E+05
1 year	2.92E+03	2.12E+04
10 years	5.53E+02	3.51E+03
100 years	1.56E+00	1.25E+02
1000 years	1.52E+00	1.12E+01
10^4 years	1.52E+00	1.96E-01

Total Activity w/o Tritium (Ci)

@	lipb	impurities
Shutdown	3.98E+09	1.61E+08
1 year	9.53E+05	6.91E+06
10 years	1.81E+05	1.15E+06
100 years	5.08E+02	4.09E+04
1000 years	4.97E+02	3.66E+03
10^4 years	4.96E+02	6.39E+01

Contact Dose (mSv/hr)

@	lipb	impurities
Shutdown	2.84E+07	1.68E+07
1 year	8.60E+00	5.06E+05
10 years	6.04E-01	1.13E+05
100 years	1.06E-01	1.71E+02
1000 years	2.19E-02	2.25E+00
10^4 years	2.14E-02	1.15E+00

Life Cycle Waste Volume (m^3)

lipb	3.27E+02

Deep Disposal Index
1.31E+03

A.4. Reference V/Li Design (R3)

Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	5.86E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.52E-05
structure	1.93E-03	1.48E+00	3.69E-03	1.77E-05	7.06E-03	3.17E-04
impurities	1.93E-01	3.21E+00	2.64E-01	2.13E-02	3.24E-02	1.89E-03

Structure Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
si	1.80E-03	0.00E+00	0.00E+00	1.53E-05	0.00E+00	0.00E+00
nb	1.93E-01	0.00E+00	2.64E-01	2.13E-02	2.16E-02	1.12E-03
cr	5.22E-07	0.00E+00	6.62E-07	1.01E-08	0.00E+00	0.00E+00
ti	2.78E-05	0.00E+00	0.00E+00	2.44E-07	0.00E+00	0.00E+00
al	0.00E+00	1.11E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ag	0.00E+00	3.15E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
w	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.06E-03	3.17E-04
mo	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.84E-03	4.74E-04
others	9.98E-05	4.26E-01	3.69E-03	2.17E-06	8.90E-04	2.91E-04

Specific Activity w/o Tritium (Ci/m^3) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	1.10E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+00
structure	3.15E+07	1.66E+08	2.45E+07	2.04E+06	2.30E+06	3.04E+05
impurities	4.01E+02	1.47E+05	9.92E+01	2.00E+01	2.26E+05	3.53E+04

Specific Activity w/o Tritium (Ci/m^3) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	3.81E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E-02
structure	5.24E+05	1.65E+06	5.42E+05	6.38E+03	1.88E+05	4.42E+04
impurities	7.99E+00	1.86E+03	1.00E+01	1.99E-01	3.22E+02	4.53E+01

Specific Activity w/o Tritium (Ci/m^3) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	1.00E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.05E-04
structure	5.59E+02	6.52E+05	5.94E+02	6.43E+00	1.55E+04	4.13E+03
impurities	4.89E+00	7.61E+01	6.47E+00	2.00E-01	3.61E+01	1.37E+01

Specific Activity w/o Tritium (Ci/m^3) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	7.96E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-04
structure	1.49E-01	1.24E+05	1.94E-01	1.12E-03	2.86E-01	1.32E-02
impurities	1.46E-01	0.00E+00	1.99E-01	7.97E-03	1.87E+01	7.31E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	9.68E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.39E-06
structure	2.35E-03	2.44E+02	4.82E-03	2.32E-05	2.84E-01	1.29E-02
impurities	3.94E-02	9.20E-02	5.54E-02	4.10E-03	5.62E-01	1.96E-01

Specific Activity w/o Tritium (Ci/m^3) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	1.88E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.68E-06
structure	1.69E-04	1.47E-01	3.39E-04	1.42E-06	2.76E-01	1.26E-02
impurities	2.70E-02	1.33E-01	3.70E-02	3.00E-03	3.68E-01	1.28E-01

Total Activity w/o Tritium (Ci) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	6.85E+08	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.87E+01
structure	1.03E+09	4.58E+09	1.52E+09	2.40E+08	8.07E+07	1.21E+08
impurities	1.31E+04	4.04E+06	6.15E+03	2.35E+03	7.94E+06	1.40E+07

Total Activity w/o Tritium (Ci) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	2.37E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E+00
structure	1.71E+07	4.55E+07	3.36E+07	7.50E+05	6.62E+06	1.76E+07
impurities	2.60E+02	5.12E+04	6.21E+02	2.34E+01	1.13E+04	1.80E+04

Total Activity w/o Tritium (Ci) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	6.22E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.80E-02
structure	1.82E+04	1.79E+07	3.68E+04	7.56E+02	5.43E+05	1.64E+06
impurities	1.59E+02	2.09E+03	4.01E+02	2.35E+01	1.27E+03	5.45E+03

Total Activity w/o Tritium (Ci) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	4.95E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.04E-03
structure	4.85E+00	3.41E+06	1.20E+01	1.31E-01	1.00E+01	5.25E+00
impurities	4.76E+00	0.00E+00	1.23E+01	9.38E-01	6.58E+02	2.90E+03

Total Activity w/o Tritium (Ci) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	6.02E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.19E-04
structure	7.65E-02	6.71E+03	2.99E-01	2.73E-03	9.98E+00	5.14E+00
impurities	1.29E+00	2.53E+00	3.43E+00	4.83E-01	1.97E+01	7.77E+01

Total Activity w/o Tritium (Ci) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	1.17E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.77E-04
structure	5.52E-03	4.04E+00	2.10E-02	1.67E-04	9.68E+00	5.00E+00
impurities	8.81E-01	3.66E+00	2.29E+00	3.53E-01	1.29E+01	5.09E+01

Contact Dose (mSv/hr) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	7.17E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.39E+01
structure	9.78E+08	1.58E+09	6.69E+08	5.89E+07	1.06E+07	1.29E+06
impurities	0.00E+00	2.34E+08	0.00E+00	1.34E+06	5.55E+06	8.65E+05

Contact Dose (mSv/hr) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	7.45E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E+00
structure	4.90E+05	4.72E+07	3.79E+05	1.02E+04	5.44E+05	5.65E+04
impurities	3.01E+00	1.94E+04	3.01E+00	1.00E-01	3.17E+03	3.49E+02

Contact Dose (mSv/hr) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	5.66E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.58E-03
structure	2.84E+00	1.44E+07	3.42E+00	2.64E-02	1.86E+03	1.35E+02
impurities	1.17E+00	3.27E+06	1.60E+00	1.30E-01	6.68E+01	7.49E+00

Contact Dose (mSv/hr) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	8.67E-01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.13E-03
structure	3.90E-01	1.08E+02	4.64E-01	2.25E-03	1.39E-02	9.67E-04
impurities	1.17E+00	1.11E+02	1.59E+00	1.30E-01	9.43E-02	4.96E-03

Contact Dose (mSv/hr) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	2.83E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-05
structure	8.87E-03	3.70E+00	1.74E-02	7.55E-05	6.80E-04	2.96E-05
impurities	1.13E+00	8.65E-01	1.54E+00	1.26E-01	9.10E-02	4.76E-03

Contact Dose (mSv/hr) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	2.83E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45E-06
structure	8.80E-03	3.66E+00	1.72E-02	7.48E-05	6.59E-04	2.88E-05
impurities	8.31E-01	4.35E-02	1.14E+00	9.25E-02	6.71E-02	3.52E-03

Life Cycle Waste Volume (m^3)

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
cao	0.00E+00	0.00E+00	0.00E+00	6.22E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.92E+01
structure	3.26E+01	2.75E+01	6.20E+01	1.18E+02	3.51E+01	3.97E+02

Deep Disposal Index
1.29E+02

A.5. Liquid Breeder for Design R3 - Lithium

Waste Disposal Rating

li	6.01E-02
impurities	1.76E-03

Breeder Waste Disposal Rating

li	6.06E-02
k	1.04E-03
n	5.49E-04
ca	5.11E-05
others	0.00E+00

Specific Activity w/o Tritium (Ci/m^3)

@	li	impurities
Shutdown	3.92E+05	2.14E+03
1 year	0.00E+00	9.02E+01
10 years	0.00E+00	1.95E+01
100 years	0.00E+00	1.05E+01
1000 years	0.00E+00	1.30E+00
10^4 years	0.00E+00	1.07E-01

Total Activity w/o Tritium (Ci)

@	li	impurities
Shutdown	1.85E+08	1.01E+06
1 year	0.00E+00	4.25E+04
10 years	0.00E+00	9.18E+03
100 years	0.00E+00	4.94E+03
1000 years	0.00E+00	6.13E+02
10^4 years	0.00E+00	5.03E+01

Contact Dose (mSv/hr)

@	li	impurities
Shutdown	0.00E+00	5.24E+04
1 year	0.00E+00	2.61E+03
10 years	0.00E+00	2.37E+02
100 years	0.00E+00	4.20E-05
1000 years	0.00E+00	4.20E-05
10^4 years	0.00E+00	4.18E-05

Life Cycle Waste Volume (m^3)

li	4.72E+02

Deep Disposal Index

0.00E+00

A.6. Reference $SiC/Li_2ZrO_3/He$ Design (R4)

Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	4.27E-02	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	2.27E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.71E-05
structure	1.59E+00	1.55E+00	2.71E+00	1.55E-02	7.62E-03	9.71E-05
impurities	0.00E+00	4.97E+00	1.00E-05	7.97E-07	2.00E-02	8.87E-04

Structure Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
si	1.59E+00	0.00E+00	2.71E+00	1.52E-02	0.00E+00	0.00E+00
c	2.77E-04	0.00E+00	3.62E-04	3.86E-04	0.00E+00	0.00E+00
al	0.00E+00	1.14E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ag	0.00E+00	4.79E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
w	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.60E-03	9.69E-05
mo	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.39E-03	1.91E-04
nb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-02	5.02E-04
others	0.00E+00	5.95E-01	0.00E+00	0.00E+00	3.82E-03	1.94E-04

Specific Activity w/o Tritium (Ci/m^3) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	1.66E+06	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	9.08E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E+00
structure	3.82E+07	1.96E+08	2.94E+07	1.48E+06	3.45E+06	1.65E+05
impurities	2.50E+03	1.85E+05	2.30E+03	2.70E+02	4.68E+05	2.24E+04

Specific Activity w/o Tritium (Ci/m^3) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	1.33E+03	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	1.10E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.14E-02
structure	1.81E+01	1.90E+06	3.27E+01	3.32E-01	5.58E+05	2.85E+04
impurities	1.18E+03	4.81E+03	1.16E+03	1.31E+02	3.14E+02	2.43E+01

Specific Activity w/o Tritium (Ci/m^3) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	1.70E+02	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	1.55E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.45E-04
structure	2.20E+00	7.42E+05	3.75E+00	2.53E-01	5.38E+04	2.70E+03
impurities	3.00E+02	2.29E+02	3.00E+02	3.83E+01	1.89E+02	9.35E+00

Specific Activity w/o Tritium (Ci/m^3) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	1.49E+01	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	6.73E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-04
structure	6.08E-01	1.40E+05	8.53E-01	2.42E-01	3.02E-01	4.26E-03
impurities	2.08E-03	0.00E+00	2.19E-03	2.00E-04	1.02E+02	5.01E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	7.15E+00	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	1.94E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.82E-06
structure	5.96E-01	2.76E+02	8.36E-01	2.19E-01	3.01E-01	3.71E-03
impurities	1.01E-04	1.08E-01	1.99E-04	0.00E+00	2.67E+00	1.33E-01

Specific Activity w/o Tritium (Ci/m^3) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	2.69E+00	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	1.28E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06
structure	5.23E-01	1.52E-01	7.41E-01	8.37E-02	2.91E-01	3.92E-03
impurities	9.40E-05	1.47E-01	1.90E-04	0.00E+00	1.74E+00	8.74E-02

Total Activity w/o Tritium (Ci) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	3.35E+08	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	2.46E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E+02
structure	7.13E+08	2.71E+09	8.64E+08	1.12E+09	1.27E+08	5.79E+07
impurities	4.66E+04	2.57E+06	6.76E+04	2.04E+05	1.72E+07	7.85E+06

Total Activity w/o Tritium (Ci) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	2.68E+05	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	2.99E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.46E+00
structure	3.37E+02	2.63E+07	9.61E+02	2.51E+02	2.05E+07	1.00E+07
impurities	2.21E+04	6.67E+04	3.42E+04	9.87E+04	1.16E+04	8.54E+03

Total Activity w/o Tritium (Ci) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	3.42E+04	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	4.21E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.05E-02
structure	4.10E+01	1.03E+07	1.10E+02	1.91E+02	1.98E+06	9.49E+05
impurities	5.61E+03	3.18E+03	8.82E+03	2.89E+04	6.96E+03	3.29E+03

Total Activity w/o Tritium (Ci) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	3.01E+03	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	1.83E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.33E-03
structure	1.13E+01	1.94E+06	2.51E+01	1.83E+02	1.11E+01	1.50E+00
impurities	3.88E-02	0.00E+00	6.44E-02	1.51E-01	3.75E+03	1.76E+03

Total Activity w/o Tritium (Ci) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	1.45E+03	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	5.28E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.46E-04
structure	1.11E+01	3.82E+03	2.46E+01	1.65E+02	1.11E+01	1.30E+00
impurities	1.88E-03	1.50E+00	5.85E-03	0.00E+00	9.82E+01	4.68E+01

Total Activity w/o Tritium (Ci) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	5.43E+02	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	3.46E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.94E-04
structure	9.77E+00	2.10E+00	2.18E+01	6.33E+01	1.07E+01	1.38E+00
impurities	1.75E-03	2.03E+00	5.59E-03	0.00E+00	6.39E+01	3.07E+01

Contact Dose (mSv/hr) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	8.90E+05	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	7.15E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.73E+01
structure	2.40E+09	1.73E+09	1.85E+09	8.68E+07	1.26E+07	7.77E+05
impurities	1.00E+05	1.45E+06	1.00E+05	1.25E+04	1.15E+07	4.61E+05

Contact Dose (mSv/hr) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	3.67E+04	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	1.01E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.56E+00
structure	1.47E+03	5.40E+07	2.67E+03	7.36E+00	4.77E+05	2.99E+04
impurities	8.10E+04	1.00E+05	8.14E+04	1.10E+04	1.36E+03	1.67E+02

Contact Dose (mSv/hr) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	8.29E+03	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	3.89E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.41E-03
structure	1.46E+02	1.64E+07	2.65E+02	7.93E-01	5.12E+03	5.90E+01
impurities	2.45E+04	3.00E+02	2.47E+04	3.37E+03	3.99E+01	4.39E+00

Contact Dose (mSv/hr) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	1.90E-01	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	6.58E-03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.59E-03
structure	1.42E+01	1.22E+02	2.42E+01	1.36E-01	3.77E-02	4.10E-04
impurities	1.78E-01	1.70E+02	1.78E-01	2.44E-02	5.13E-02	2.21E-03

Contact Dose (mSv/hr) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	1.28E-01	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	5.86E-03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.06E-05
structure	1.42E+01	3.79E+00	2.42E+01	1.36E-01	7.95E-04	7.38E-06
impurities	0.00E+00	1.37E+00	0.00E+00	0.00E+00	4.94E-02	2.13E-03

Contact Dose (mSv/hr) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	1.25E-01	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	4.63E-03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-06
structure	1.41E+01	3.76E+00	2.40E+01	1.35E-01	8.51E-04	8.75E-06
impurities	0.00E+00	1.00E-01	2.00E-04	0.00E+00	3.64E-02	1.57E-03

Life Cycle Waste Volume (m^3)

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
be	0.00E+00	0.00E+00	0.00E+00	2.02E+02	0.00E+00	0.00E+00
lizro	0.00E+00	0.00E+00	0.00E+00	2.71E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.94E+01
structure	1.87E+01	1.39E+01	2.94E+01	7.56E+02	3.68E+01	3.51E+02

Deep Disposal Index

2.00E+02

A.7 $V/Li_2O/H_2O$ Variant Design - (V1)

Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	8.63E-02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.73E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	7.59E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-04
structure	1.84E-03	1.59E+00	3.92E-03	1.86E-05	5.19E-02	3.87E-03
impurities	2.00E-01	6.45E+00	2.73E-01	3.32E-02	9.44E-02	8.25E-03

Structure Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
nb	2.00E-01	0.00E+00	2.73E-01	3.32E-02	5.30E-02	4.36E-03
cr	5.15E-07	0.00E+00	6.85E-07	2.02E-08	0.00E+00	0.00E+00
ti	2.85E-05	0.00E+00	3.71E-05	2.60E-07	0.00E+00	0.00E+00
si	1.71E-03	0.00E+00	3.76E-03	1.41E-05	0.00E+00	0.00E+00
al	0.00E+00	1.17E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ag	0.00E+00	6.37E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
w	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.19E-02	3.87E-03
mo	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-02	1.95E-03
others	9.82E-05	4.99E-01	1.29E-04	4.45E-06	1.47E-02	1.94E-03

Specific Activity w/o Tritium (Ci/m^3) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.87E+05	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	7.89E+05	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.21E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.76E+00
structure	1.26E+08	2.16E+08	9.51E+07	5.69E+06	1.13E+07	1.42E+06
impurities	0.00E+00	2.02E+05	1.98E+02	1.00E+02	6.00E+05	1.33E+05

Specific Activity w/o Tritium (Ci/m^3) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.57E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.40E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.62E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E-01
structure	5.00E+05	1.85E+06	5.13E+05	1.09E+04	2.57E+06	3.12E+05
impurities	1.00E+01	7.67E+03	1.20E+01	6.99E-01	1.72E+04	1.36E+03

Specific Activity w/o Tritium (Ci/m^3) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.41E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.16E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.09E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.70E-04
structure	5.26E+02	7.24E+05	5.57E+02	1.04E+01	2.36E+05	2.93E+04
impurities	5.54E+00	9.80E+01	8.18E+00	5.11E-01	2.31E+02	5.87E+01

Specific Activity w/o Tritium (Ci/m^3) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.33E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.07E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.36E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E-04
structure	1.52E-01	1.41E+05	2.11E-01	9.20E-04	2.53E+00	1.89E-01
impurities	1.60E-01	0.00E+00	2.34E-01	1.72E-02	6.03E+01	2.69E+01

Specific Activity w/o Tritium (Ci/m^3) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.27E+00	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.09E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.13E-05
structure	2.27E-03	2.77E+02	5.26E-03	2.30E-05	2.52E+00	1.88E-01
impurities	4.03E-02	1.00E-01	5.62E-02	6.40E-03	1.91E+00	7.21E-01

Specific Activity w/o Tritium (Ci/m^3) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	7.79E-01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	6.16E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	4.06E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.68E-06
structure	1.61E-04	1.57E-01	3.62E-04	1.28E-06	2.46E+00	1.84E-01
impurities	2.80E-02	1.45E-01	3.81E-02	4.68E-03	1.18E+00	4.64E-01

Total Activity w/o Tritium (Ci) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	8.98E+07	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.10E+07	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.50E+08	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E+02
structure	2.81E+09	4.31E+09	3.63E+09	5.66E+08	2.61E+08	7.20E+08
impurities	0.00E+00	4.04E+06	7.56E+03	9.96E+03	1.39E+07	6.75E+07

Total Activity w/o Tritium (Ci) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.36E+04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.35E+02	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.04E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.00E+00
structure	1.12E+07	3.69E+07	1.95E+07	1.08E+06	5.97E+07	1.59E+08
impurities	2.24E+02	1.53E+05	4.57E+02	6.96E+01	3.99E+05	6.93E+05

Total Activity w/o Tritium (Ci) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	5.76E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.41E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.41E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.43E-02
structure	1.18E+04	1.45E+07	2.12E+04	1.03E+03	5.46E+06	1.49E+07
impurities	1.24E+02	1.96E+03	3.12E+02	5.08E+01	5.36E+03	2.98E+04

Total Activity w/o Tritium (Ci) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.05E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.49E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.84E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.16E-02
structure	3.40E+00	2.81E+06	8.04E+00	9.15E-02	5.87E+01	9.62E+01
impurities	3.58E+00	0.00E+00	8.93E+00	1.71E+00	1.40E+03	1.37E+04

Total Activity w/o Tritium (Ci) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	5.58E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.40E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.45E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.77E-04
structure	5.08E-02	5.53E+03	2.00E-01	2.29E-03	5.85E+01	9.56E+01
impurities	9.03E-01	2.00E+00	2.14E+00	6.37E-01	4.44E+01	3.67E+02

Total Activity w/o Tritium (Ci) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.02E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	8.60E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.16E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.96E-04
structure	3.61E-03	3.14E+00	1.38E-02	1.28E-04	5.71E+01	9.34E+01
impurities	6.27E-01	2.90E+00	1.45E+00	4.66E-01	2.74E+01	2.36E+02

Contact Dose (mSv/hr) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.97E+07	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.36E+07	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	9.25E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.26E+01
structure	4.04E+09	1.73E+09	2.90E+09	1.76E+08	5.71E+07	6.40E+06
impurities	0.00E+00	1.68E+06	0.00E+00	0.00E+00	1.40E+07	3.19E+06

Contact Dose (mSv/hr) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.40E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.03E+03	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.57E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.44E+00
structure	5.58E+05	5.20E+07	4.38E+05	2.46E+04	3.11E+06	3.07E+05
impurities	1.99E+00	2.02E+05	3.01E+00	5.03E-01	1.90E+05	1.46E+04

Contact Dose (mSv/hr) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	9.14E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.15E+02	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	7.95E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.32E-03
structure	3.22E+00	1.58E+07	4.11E+00	2.69E-02	1.11E+04	1.74E+03
impurities	1.21E+00	2.07E+06	1.65E+00	2.00E-01	3.69E+03	2.91E+02

Contact Dose (mSv/hr) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.17E-03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.33E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.25E-01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.75E-03
structure	4.01E-01	1.18E+02	5.04E-01	1.00E-03	7.61E-02	1.22E-02
impurities	1.21E+00	2.23E+02	1.64E+00	2.02E-01	2.99E-01	2.42E-02

Contact Dose (mSv/hr) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.90E-03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.33E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.65E-01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.80E-05
structure	8.44E-03	3.91E+00	1.85E-02	6.92E-05	5.08E-03	3.82E-04
impurities	1.17E+00	1.71E+00	1.59E+00	1.96E-01	2.66E-01	2.16E-02

Contact Dose (mSv/hr) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.88E-03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.31E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.62E-01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.01E-06
structure	8.37E-03	3.88E+00	1.83E-02	6.86E-05	5.04E-03	4.17E-04
impurities	8.61E-01	5.50E-02	1.17E+00	1.44E-01	2.07E-01	1.68E-02

Life Cycle Waste Volume (m^3)

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.31E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.40E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	7.79E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.12E+01
structure	2.24E+01	2.00E+01	3.81E+01	9.95E+01	2.32E+01	5.08E+02

Deep Disposal Index
1.61E+02

A.8. Variant 316SS/Li_2O/H_2O Design (V2)

Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.81E-02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.06E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.74E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.15E-05
structure	1.46E+02	1.39E+00	2.77E+02	1.37E+01	3.51E+01	2.91E+00
impurities	0.00E+00	6.52E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Structure Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
mo	1.47E+02	0.00E+00	2.79E+02	1.39E+01	3.55E+01	2.93E+00
al	0.00E+00	1.02E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ag	0.00E+00	6.05E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
others	0.00E+00	8.37E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.00E+05	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.30E+05	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.22E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.09E+00
structure	7.28E+07	2.52E+08	8.58E+07	2.47E+06	1.89E+06	3.27E+05
impurities	0.00E+00	2.19E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	8.90E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.02E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.13E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.97E-02
structure	1.99E+07	1.69E+06	2.95E+07	6.39E+05	5.63E+05	9.56E+04
impurities	0.00E+00	9.75E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.22E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.12E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.54E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.70E-04
structure	1.90E+06	6.52E+05	3.02E+06	7.06E+04	9.39E+04	1.91E+04
impurities	0.00E+00	6.41E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	5.88E+00	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.49E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	5.07E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E-04
structure	1.24E+04	1.25E+05	2.48E+04	3.77E+02	2.05E+03	9.93E+02
impurities	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.09E+00	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.33E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.31E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.73E-06
structure	5.98E+02	2.45E+02	1.18E+03	2.56E+01	6.99E+01	2.00E+01
impurities	0.00E+00	1.02E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.00E-01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.41E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.68E-01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.93E-06
structure	2.08E+02	1.34E-01	3.94E+02	8.67E+00	3.80E+01	1.49E+01
impurities	0.00E+00	1.40E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.21E+08	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.26E+07	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.69E+08	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.36E+02
structure	7.86E+09	6.99E+09	5.58E+09	5.24E+08	1.56E+08	3.04E+08
impurities	0.00E+00	6.07E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.59E+04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	7.69E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.13E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.57E+00
structure	2.15E+09	4.68E+07	1.92E+09	1.35E+08	4.64E+07	8.88E+07
impurities	0.00E+00	2.70E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.92E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.57E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.18E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.01E-02
structure	2.05E+08	1.81E+07	1.97E+08	1.50E+07	7.73E+06	1.77E+07
impurities	0.00E+00	1.78E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.37E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	9.48E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	7.02E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-02
structure	1.33E+06	3.46E+06	1.61E+06	7.99E+04	1.69E+05	9.21E+05
impurities	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.38E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	8.87E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.20E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.31E-04
structure	6.45E+04	6.80E+03	7.67E+04	5.43E+03	5.75E+03	1.85E+04
impurities	0.00E+00	2.83E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	8.05E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	5.35E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.20E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.44E-04
structure	2.25E+04	3.71E+00	2.56E+04	1.84E+03	3.12E+03	1.39E+04
impurities	0.00E+00	3.89E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	9.47E+06	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.35E+07	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.59E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.05E+01
structure	6.76E+08	1.86E+09	7.30E+08	2.58E+07	2.24E+07	4.03E+06
impurities	0.00E+00	1.91E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.73E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	6.02E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.11E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.66E+00
structure	6.68E+07	4.74E+07	1.03E+08	5.09E+06	7.53E+06	1.53E+06
impurities	0.00E+00	2.44E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.05E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	8.95E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.70E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.26E-03
structure	1.45E+07	1.43E+07	2.46E+07	9.76E+05	2.19E+06	4.58E+05
impurities	0.00E+00	1.58E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	5.24E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.82E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.74E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.40E-03
structure	1.58E+02	1.07E+02	2.81E+02	9.05E+00	1.81E+01	3.49E+00
impurities	0.00E+00	2.13E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	5.00E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.82E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.49E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.95E-05
structure	4.42E+01	3.39E+00	8.52E+01	1.70E+00	1.94E+00	1.56E-01
impurities	0.00E+00	1.83E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.95E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.79E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.44E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.86E-06
structure	2.88E+01	3.36E+00	5.51E+01	1.13E+00	1.30E+00	1.05E-01
impurities	0.00E+00	1.97E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Life Cycle Waste Volume (m^3)

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.04E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.81E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.39E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+02
structure	1.08E+02	2.77E+01	6.50E+01	2.12E+02	8.23E+01	9.28E+02

Deep Disposal Index
5.03E+04

A.9. Variant PCA/Li_2O/H_2O Design (V3)

Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.60E-02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.75E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	4.10E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.26E-05
structure	3.09E+02	8.07E-01	4.22E+02	3.47E+01	8.64E+01	1.62E+01
impurities	0.00E+00	3.98E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Structure Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
mo	2.10E+02	0.00E+00	3.18E+02	2.20E+01	4.11E+01	3.53E+00
al	1.73E-01	5.98E-01	2.83E-01	4.61E-03	4.12E-03	3.26E-04
nb	4.18E+01	0.00E+00	6.48E+01	5.29E+00	1.05E+01	9.45E-01
ag	0.00E+00	3.82E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
others	5.71E+01	3.70E-01	3.88E+01	7.41E+00	3.48E+01	1.17E+01

Specific Activity w/o Tritium (Ci/m^3) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.02E+05	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.43E+05	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.64E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.96E+00
structure	8.73E+07	1.48E+08	7.79E+07	3.07E+06	2.81E+06	4.65E+05
impurities	0.00E+00	1.39E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.10E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.45E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.40E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.89E-02
structure	2.59E+07	9.70E+05	2.69E+07	7.55E+05	6.07E+05	8.34E+04
impurities	0.00E+00	7.08E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.84E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	7.86E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.82E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.99E-04
structure	2.23E+06	3.79E+05	2.47E+06	6.78E+04	6.49E+04	1.16E+04
impurities	0.00E+00	2.60E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	9.60E+00	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.16E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.51E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E-04
structure	2.45E+04	7.15E+04	3.89E+04	8.98E+02	3.29E+03	1.57E+03
impurities	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.78E+00	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.90E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	7.04E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.49E-06
structure	1.01E+03	1.41E+02	1.58E+03	4.79E+01	1.10E+02	3.30E+01
impurities	0.00E+00	8.90E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.29E-01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.34E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.65E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.68E-06
structure	3.95E+02	7.47E-02	5.97E+02	1.92E+01	6.06E+01	2.36E+01
impurities	0.00E+00	7.99E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.26E+07	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	6.83E+06	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.94E+08	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.08E+02
structure	5.66E+09	4.14E+09	3.02E+09	4.34E+08	2.24E+08	4.47E+08
impurities	0.00E+00	3.88E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.27E+04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	8.86E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.66E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.33E+00
structure	1.68E+09	2.71E+07	1.04E+09	1.07E+08	4.84E+07	8.00E+07
impurities	0.00E+00	1.98E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.81E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.56E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.16E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.25E-02
structure	1.44E+08	1.06E+07	9.57E+07	9.58E+06	5.17E+06	1.11E+07
impurities	0.00E+00	7.26E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.99E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	8.29E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.80E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-02
structure	1.59E+06	2.00E+06	1.51E+06	1.27E+05	2.63E+05	1.51E+06
impurities	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.68E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	7.76E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.37E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.98E-04
structure	6.55E+04	3.93E+03	6.14E+04	6.78E+03	8.74E+03	3.16E+04
impurities	0.00E+00	2.48E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.81E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.66E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.15E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.11E-04
structure	2.56E+04	2.09E+00	2.32E+04	2.71E+03	4.83E+03	2.27E+04
impurities	0.00E+00	2.23E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	9.54E+06	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.39E+07	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.87E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.09E+01
structure	8.21E+08	1.08E+09	6.75E+08	3.82E+07	3.30E+07	6.22E+06
impurities	0.00E+00	3.29E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.33E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.35E+02	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.61E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E+00
structure	4.78E+07	2.76E+07	4.89E+07	2.15E+06	2.32E+06	3.23E+05
impurities	0.00E+00	1.97E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.81E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.81E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.81E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.35E-03
structure	5.89E+06	8.40E+06	7.52E+06	3.36E+05	4.76E+05	7.84E+04
impurities	0.00E+00	5.96E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	8.89E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	6.35E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	8.04E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.45E-03
structure	7.60E+02	6.27E+01	7.98E+02	8.57E+01	3.03E+02	1.11E+02
impurities	0.00E+00	1.34E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	8.45E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	6.35E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	5.23E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E-05
structure	2.69E+02	1.99E+00	3.91E+02	3.25E+01	6.49E+01	1.03E+01
impurities	0.00E+00	1.05E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	8.38E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	6.29E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	5.12E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.12E-06
structure	1.71E+02	1.97E+00	2.63E+02	1.80E+01	3.41E+01	3.05E+00
impurities	0.00E+00	5.01E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Life Cycle Waste Volume (m^3)

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.07E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.99E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.19E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E+02
structure	6.48E+01	2.79E+01	3.88E+01	1.41E+02	7.97E+01	9.60E+02

Deep Disposal Index
7.70E+04

A.10. Variant VA64/Li_2O/H_2O Design - (V4)

Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.97E-02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.31E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.81E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.69E-05
structure	1.04E+03	1.71E+00	1.59E+03	1.07E+02	5.54E+02	5.29E+01
impurities	0.00E+00	6.46E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Structure Waste Disposal Rating

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
mo	7.28E+01	0.00E+00	1.09E+02	5.68E+00	2.75E+01	2.52E+00
nb	9.73E+02	0.00E+00	1.48E+03	1.01E+02	5.26E+02	5.02E+01
al	0.00E+00	1.26E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ag	0.00E+00	6.14E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cu	0.00E+00	4.48E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
others	0.00E+00	3.28E-01	0.00E+00	0.00E+00	4.16E-01	1.96E-01

Specific Activity w/o Tritium (Ci/m^3) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.63E+05	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	6.83E+05	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.42E+06	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E+00
structure	1.69E+08	2.17E+08	1.46E+08	5.93E+06	7.99E+06	1.60E+06
impurities	0.00E+00	2.05E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.47E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	3.51E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.20E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.68E-02
structure	2.79E+07	2.02E+06	3.31E+07	7.84E+05	8.46E+05	1.08E+05
impurities	0.00E+00	8.15E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.64E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	5.84E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	9.82E+01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.07E-04
structure	1.96E+06	7.89E+05	2.54E+06	5.56E+04	8.37E+04	1.15E+04
impurities	0.00E+00	4.54E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	7.31E+00	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.90E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	4.74E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-04
structure	1.93E+03	1.51E+05	3.04E+03	1.04E+02	6.01E+02	1.16E+02
impurities	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.31E+00	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.72E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	2.10E+00	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.50E-06
structure	9.29E+02	2.97E+02	1.45E+03	5.05E+01	3.46E+02	6.92E+01
impurities	0.00E+00	1.13E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Specific Activity w/o Tritium (Ci/m^3) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.33E-01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.68E-01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	7.87E-01	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.63E-06
structure	3.32E+02	1.71E-01	5.14E+02	2.30E+01	1.53E+02	2.70E+01
impurities	0.00E+00	1.61E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.98E+08	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.81E+07	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.55E+08	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E+02
structure	5.95E+09	3.70E+09	8.74E+09	1.38E+09	9.27E+07	7.71E+08
impurities	0.00E+00	3.49E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.59E+04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.44E+02	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.76E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.94E+00
structure	9.83E+08	3.43E+07	1.99E+09	1.82E+08	9.82E+06	5.20E+07
impurities	0.00E+00	1.39E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	7.40E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.40E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.44E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.09E-02
structure	6.90E+07	1.34E+07	1.52E+08	1.29E+07	9.70E+05	5.56E+06
impurities	0.00E+00	7.72E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.29E+03	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.19E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	6.95E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.42E-03
structure	6.79E+04	2.56E+06	1.82E+05	2.43E+04	6.97E+03	5.62E+04
impurities	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	5.91E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.12E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.08E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.85E-04
structure	3.27E+04	5.04E+03	8.70E+04	1.17E+04	4.01E+03	3.34E+04
impurities	0.00E+00	1.92E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Total Activity w/o Tritium (Ci) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	1.05E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	6.92E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.15E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E-04
structure	1.17E+04	2.91E+00	3.09E+04	5.34E+03	1.77E+03	1.30E+04
impurities	0.00E+00	2.73E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ Shutdown

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	2.16E+07	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	2.86E+07	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	5.27E+05	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.31E+01
structure	2.64E+09	1.84E+09	2.06E+09	1.03E+08	1.54E+08	3.29E+07
impurities	0.00E+00	1.74E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 1 year

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.70E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.09E+02	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.02E+04	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.99E+00
structure	1.10E+08	5.71E+07	1.09E+08	3.59E+06	3.57E+06	4.48E+05
impurities	0.00E+00	1.98E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 10 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	3.04E+01	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	1.43E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.72E+03	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.74E-03
structure	1.67E+06	1.73E+07	2.29E+06	1.05E+05	5.12E+05	8.75E+04
impurities	0.00E+00	6.00E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 100 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.83E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.79E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	4.37E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-03
structure	4.30E+03	1.30E+02	6.53E+03	4.47E+02	2.33E+03	2.24E+02
impurities	0.00E+00	2.16E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 1000 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.47E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.79E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.10E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.18E-05
structure	4.14E+03	4.22E+00	6.29E+03	4.31E+02	2.25E+03	2.15E+02
impurities	0.00E+00	1.77E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Contact Dose (mSv/hr) @ 10^4 years

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	6.41E-04	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.75E+00	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	3.03E-02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.12E-06
structure	3.04E+03	4.18E+00	4.62E+03	3.17E+02	1.66E+03	1.58E+02
impurities	0.00E+00	1.40E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Life Cycle Waste Volume (m^3)

	First Wall	Divertor Plate	Divertor Wall	Blanket	Vacuum Vessel	Shield
li2o	0.00E+00	0.00E+00	0.00E+00	4.50E+02	0.00E+00	0.00E+00
almina	0.00E+00	0.00E+00	0.00E+00	4.11E+01	0.00E+00	0.00E+00
be	0.00E+00	0.00E+00	0.00E+00	1.47E+02	0.00E+00	0.00E+00
pb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.14E+01
structure	3.52E+01	1.70E+01	6.01E+01	2.33E+02	1.16E+01	4.83E+02

Deep Disposal Index

2.55E+05

APPENDIX B

PARAMETER FITTING DATA

The following data in this appendix is the results of the parameter fitting for each component in the designs that were analyzed. The results are organized by design with the results for each component in that design listed.

The reported results for each component include the fitting parameters a and b and the maximum difference between the calculated value and the actual value for any single data point in that set and the number of data points or cases that were in the data set.

For example, the results for the contact dose at 1000 years after shutdown for the divertor plate in the FeS/Li_2O/H_2O design (R1) is

$$CD(mSv/hr)@1000years = -3.2766E\text{-}16 \times \phi\ (n/cm^2\text{-}sec) + 1.3750E{+}22 \times \phi t(n/cm^2).$$

The maximum error for this fit was 3.05% and there were 7 data points used to generate the fit.

B.1. Reference $FeS/Li_2O/H_2O$ Design (R1)

First Wall / Divertor Wall

	a	b	Max. Error(%)	#Cases
WDR	1.3858E-18	8.0593E-24	3.4498E+01	8
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	1.7601E-07	2.9120E-16	4.8134E+00	8
1 year	4.2106E-08	2.2675E-16	8.9677E+00	8
10 years	3.8029E-09	2.2294E-17	9.3472E+00	8
100 years	2.2657E-14	2.9841E-21	4.1686E+00	8
1000 years	2.3305E-16	2.8133E-22	3.8816E+01	8
10^4 years	1.1756E-16	2.4396E-22	4.6638E+01	8
Contact Dose Rate (mSv/hr)				
Shutdown	1.3428E-06	6.6577E-16	1.8380E+01	8
1 year	4.9347E-08	1.0001E-16	1.3385E+01	8
10 years	-7.8884E-12	1.8796E-18	1.7193E+02	8
100 years	-2.9664E-16	2.9335E-23	4.1045E+01	8
1000 years	8.0682E-17	1.4277E-23	5.8808E+00	8
10^4 years	6.0848E-17	1.2845E-23	4.6954E+00	8

Divertor Plate

	a	b	Max. Error(%)	#Cases
WDR	-1.7730E-15	2.0706E-22	1.7251E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	6.4536E-07	6.4575E-17	8.4957E-01	7
1 year	1.5740E-09	3.0376E-17	1.1158E+01	7
10 years	4.2514E-10	1.3407E-17	8.2817E+00	7
100 years	1.9184E-11	3.1704E-18	3.1699E+00	7
1000 years	3.7698E-14	6.2430E-21	3.1951E+00	7
10^4 years	-1.7675E-17	7.3823E-24	5.2149E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	4.8950E-06	7.9632E-16	8.8409E-01	7
1 year	4.5872E-08	8.3284E-16	1.2943E+01	7
10 years	-1.3951E-08	5.2518E-16	8.2352E+01	7
100 years	4.4129E-14	7.6422E-21	7.7827E+00	7
1000 years	-3.2766E-16	1.3570E-22	3.0513E+00	7
10^4 years	4.5248E-17	9.2388E-23	1.1828E+00	7

Blanket

	a	b	Max. Error(%)	#Cases
WDR	1.3779E-15	-4.0670E-24	9.1714E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	9.9961E-08	3.7350E-17	3.8899E+00	7
1 year	2.0004E-08	5.9887E-17	4.4975E+00	7
10 years	1.6622E-09	6.2182E-18	6.3681E+00	7
100 years	3.7578E-13	-1.3906E-21	1.7540E+02	7
1000 years	1.9381E-14	-1.3680E-24	7.9237E+01	7
10^4 years	1.3386E-14	2.0393E-23	9.8927E+01	7
Contact Dose Rate (mSv/hr)				
Shutdown	1.2103E-06	-2.2434E-15	3.7779E+01	7
1 year	4.0163E-08	-4.7259E-18	2.8693E+01	7
10 years	2.4624E-10	-5.9384E-19	1.5419E+02	7
100 years	5.3170E-15	-1.8338E-23	1.1302E+02	7
1000 years	3.6217E-15	-1.3920E-23	9.6757E+02	7
10^4 years	2.9113E-15	-1.1171E-23	7.8696E+02	7

Vacuum Vessel

	a	b	Max. Error(%)	#Cases
WDR	-1.3267E-15	7.5201E-24	3.1462E+02	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	9.5655E-08	7.0320E-18	4.4772E+00	7
1 year	1.9028E-08	4.0707E-18	1.4488E+01	7
10 years	1.6386E-09	5.4103E-19	1.6500E+01	7
100 years	-2.9579E-13	2.8341E-21	4.3876E+03	7
1000 years	-4.8812E-14	2.6141E-22	1.5331E+02	7
10^4 years	-4.4071E-14	2.2425E-22	1.7862E+02	7
Contact Dose Rate (mSv/hr)				
Shutdown	6.9047E-07	-1.6144E-16	2.2886E+01	7
1 year	3.5662E-08	-1.2534E-17	1.1470E+01	7
10 years	-5.0137E-10	1.8317E-18	6.5135E+02	7
100 years	-4.4720E-15	2.2635E-23	5.8677E+02	7
1000 years	-7.3324E-16	9.1009E-24	8.6385E+03	7
10^4 years	-5.9861E-16	7.0649E-24	6.7742E+03	7

Shield

	a	b	Max. Error(%)	#Cases
WDR	3.1756E-17	2.6926E-24	1.3838E+00	6

Specific Actvity w/o Tritium (Ci/m^3)

Shutdown	2.9355E-11	-2.4348E-21	4.5123E+00	6
1 year	5.0973E-13	2.5013E-23	4.8338E-01	6
10 years	1.9926E-15	1.0495E-23	7.6088E+00	6
100 years	5.6409E-17	5.0692E-24	1.3070E+00	6
1000 years	4.0747E-19	3.3552E-25	1.5215E-01	6
10^4 years	4.7889E-22	3.0071E-25	1.3713E-03	6

Contact Dose Rate (mSv/hr)

Shutdown	2.6476E-10	6.5040E-22	7.7840E-02	6
1 year	1.9183E-11	3.5271E-22	2.8455E-01	6
10 years	3.2706E-15	1.7321E-22	5.4801E+00	6
100 years	1.2264E-15	1.0403E-22	1.3824E+00	6
1000 years	9.0207E-18	8.6200E-25	1.2337E+00	6
10^4 years	-2.0176E-22	9.5420E-26	1.5360E-03	6

B.2. Reference MS/$Li_{17}Pb_{83}$/H_2O Design (R2)

First Wall / Divertor Wall

	a	b	Max. Error(%)	#Cases
WDR	4.6327E-14	4.1097E-21	1.4036E+01	8

Specific Actvity w/o Tritium (Ci/m^3)

Shutdown	8.6554E-08	2.3005E-16	8.1094E+00	8
1 year	2.7993E-08	1.6727E-16	8.9642E+00	8
10 years	2.5109E-09	1.6653E-17	8.2376E+00	8
100 years	1.2116E-13	1.7719E-20	3.9938E+00	8
1000 years	2.0378E-14	4.2269E-21	7.6417E+00	8
10^4 years	8.7793E-15	9.2086E-22	1.2788E+01	8

Contact Dose Rate (mSv/hr)

Shutdown	9.2915E-07	3.8608E-16	8.6028E+00	8
1 year	3.7193E-08	8.7508E-17	1.9030E+01	8
10 years	4.4999E-10	6.4619E-18	7.0797E+00	8
100 years	1.4962E-13	1.3985E-20	1.3752E+01	8
1000 years	1.4194E-13	1.3453E-20	1.3848E+01	8
10^4 years	1.0435E-13	9.8660E-21	1.3870E+01	8

Divertor Plate

	a	b	Max. Error(%)	#Cases
WDR	-1.3874E-15	1.3675E-22	1.5389E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	4.2521E-07	4.3516E-17	8.2380E-01	7
1 year	1.1008E-09	2.1658E-17	1.1067E+01	7
10 years	2.9289E-10	9.5760E-18	8.0241E+00	7
100 years	1.0435E-11	2.2711E-18	1.8778E+00	7
1000 years	2.0506E-14	4.4723E-21	1.9031E+00	7
10^4 years	-2.0623E-17	5.6640E-24	6.1749E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	3.5243E-06	5.9008E-16	1.5158E+01	7
1 year	3.2255E-08	5.9272E-16	1.2949E+01	7
10 years	-2.9741E-09	3.1031E-16	6.0427E+01	7
100 years	4.0569E-14	4.9002E-21	6.6464E+00	7
1000 years	-3.9734E-16	9.9073E-23	1.5291E+00	7
10^4 years	-1.3910E-16	7.1542E-23	1.6893E+00	7

Blanket

	a	b	Max. Error(%)	#Cases
WDR	-1.6569E-13	5.5316E-21	8.5429E+00	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	3.2939E-08	4.0289E-17	3.4059E+00	7
1 year	1.0185E-08	3.6294E-17	7.5458E+00	7
10 years	8.9154E-10	3.8916E-18	8.2444E+00	7
100 years	-7.3250E-14	8.9425E-21	2.2017E+00	7
1000 years	-7.1000E-14	2.6655E-21	7.3972E+00	7
10^4 years	-3.0168E-14	9.8700E-22	8.7652E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	3.6423E-07	-1.1522E-16	3.8776E+00	7
1 year	1.9693E-08	5.8129E-19	3.4278E+01	7
10 years	3.6304E-10	3.7739E-18	6.0354E+00	7
100 years	-5.8079E-13	1.9555E-20	8.5206E+00	7
1000 years	-5.6527E-13	1.8918E-20	8.5417E+00	7
10^4 years	-4.1554E-13	1.3905E-20	8.5444E+00	7

Vacuum Vessel

	a	b	Max. Error(%)	#Cases
WDR	1.5001E-12	2.0298E-21	6.4964E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	3.3423E-08	5.0111E-18	4.6579E+00	7
1 year	8.6305E-09	2.4438E-18	1.7097E+01	7
10 years	9.1128E-10	3.2195E-19	1.8933E+01	7
100 years	2.9929E-12	2.0755E-20	2.8095E+01	7
1000 years	4.7395E-13	1.1574E-21	5.2739E+01	7
10^4 years	3.1123E-13	4.4240E-22	6.3652E+01	7
Contact Dose Rate (mSv/hr)				
Shutdown	4.0322E-07	-1.1990E-18	2.6594E+01	7
1 year	1.3888E-08	8.7354E-18	2.0925E+01	7
10 years	3.2597E-09	2.1737E-18	3.1148E+01	7
100 years	5.1052E-12	8.2374E-21	6.1884E+01	7
1000 years	4.9278E-12	7.9702E-21	6.2047E+01	7
10^4 years	3.6239E-12	5.8602E-21	6.2049E+01	7

Shield

	a	b	Max. Error(%)	#Cases
WDR	3.3254E-17	2.8184E-24	1.3850E+00	6
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	2.2861E-11	-1.5674E-21	3.8574E+00	6
1 year	1.0393E-12	2.6271E-23	3.4586E-01	6
10 years	1.6794E-15	1.0183E-23	5.9032E+00	6
100 years	5.8708E-17	5.1946E-24	1.3278E+00	6
1000 years	4.2754E-19	2.6452E-25	1.9906E-01	6
10^4 years	1.2380E-22	2.2813E-25	1.3607E-03	6
Contact Dose Rate (mSv/hr)				
Shutdown	2.9354E-10	-4.7557E-20	8.6043E+00	6
1 year	4.1384E-11	5.2035E-22	2.9328E-01	6
10 years	7.0136E-15	1.8659E-22	7.4895E+00	6
100 years	1.3411E-15	1.1369E-22	1.3841E+00	6
1000 years	9.8803E-18	9.0874E-25	1.2808E+00	6
10^4 years	1.7241E-21	7.1324E-26	4.1576E-03	6

B.3. Reference V/Li Design (R3)

First Wall / Divertor Wall

	a	b	Max. Error(%)	#Cases
WDR	9.2269E-18	1.6983E-24	6.2804E+00	8
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	4.7934E-08	4.5131E-18	2.4714E+00	8
1 year	3.4935E-10	2.2832E-18	1.3964E+02	8
10 years	3.2071E-13	2.7303E-21	1.6596E+02	8
100 years	2.6934E-17	2.3214E-24	9.7715E+01	8
1000 years	-1.7889E-18	3.8734E-25	6.3467E+00	8
10^4 years	1.3250E-18	2.3688E-25	6.7896E+00	8
Contact Dose Rate (mSv/hr)				
Shutdown	1.2031E-06	-2.8565E-17	9.6298E-01	8
1 year	7.5344E-10	3.1889E-20	1.4405E+00	8
10 years	8.5381E-16	2.8070E-23	1.9263E+02	8
100 years	1.6068E-16	1.2498E-23	2.0509E+01	8
1000 years	5.4351E-17	9.9186E-24	6.6776E+00	8
10^4 years	3.8331E-17	7.3249E-24	6.4086E+00	8

Divertor Plate

	a	b	Max. Error(%)	#Cases
WDR	-5.8324E-16	1.2605E-22	1.8089E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	4.8030E-07	5.0947E-17	7.1398E-01	7
1 year	1.3665E-09	2.9265E-17	1.0279E+01	7
10 years	3.8945E-10	1.2820E-17	7.4792E+00	7
100 years	1.0601E-11	3.0099E-18	1.3140E+00	7
1000 years	2.0865E-14	5.9261E-21	1.3222E+00	7
10^4 years	-1.4096E-17	7.2211E-24	6.5557E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	4.6613E-06	1.1611E-15	1.3234E+01	7
1 year	4.2455E-08	8.0060E-16	1.2296E+01	7
10 years	1.2224E-08	3.0023E-16	3.3131E+01	7
100 years	9.1835E-14	4.6295E-21	4.8057E+00	7
1000 years	-4.5818E-18	1.1595E-22	1.6101E+00	7
10^4 years	5.9038E-18	9.4054E-23	1.4874E+00	7

Blanket

	a	b	Max. Error(%)	#Cases
WDR	1.4461E-17	2.3688E-24	1.8215E+00	7

Specific Actvity w/o Tritium (Ci/m^3)

Shutdown	9.9732E-09	3.0769E-19	3.8682E-01	7
1 year	2.5477E-11	4.2082E-20	1.4276E-01	7
10 years	1.6089E-13	4.0855E-20	9.1775E-01	7
100 years	1.2637E-13	3.2533E-20	9.1128E-01	7
1000 years	1.1824E-14	3.9738E-21	6.7747E-01	7
10^4 years	-6.6291E-16	7.8735E-22	3.2254E-01	7

Contact Dose Rate (mSv/hr)

Shutdown	6.5503E-08	-7.4563E-19	1.3311E-01	7
1 year	1.8824E-12	-5.6015E-21	1.0357E+03	7
10 years	3.2254E-15	2.2031E-22	3.3045E+00	7
100 years	5.0302E-16	3.3580E-23	1.9419E+01	7
1000 years	-3.3263E-18	1.1931E-24	1.1062E+00	7
10^4 years	-3.3348E-18	1.1932E-24	1.1069E+00	7

Vacuum Vessel

	a	b	Max. Error(%)	#Cases
WDR	-1.3099E-15	1.0570E-23	5.9190E+01	7

Specific Actvity w/o Tritium (Ci/m^3)

Shutdown	1.2996E-07	-1.6673E-17	4.3517E+00	7
1 year	9.0079E-09	-1.5691E-19	1.4168E+01	7
10 years	6.3784E-10	2.9389E-19	1.4866E+01	7
100 years	5.2693E-14	2.8111E-21	4.7858E+00	7
1000 years	-6.3690E-14	3.4367E-22	1.5884E+02	7
10^4 years	-6.2461E-14	3.0779E-22	2.2407E+02	7

Contact Dose Rate (mSv/hr)

Shutdown	1.0136E-06	-6.9352E-16	9.2241E+00	7
1 year	3.6440E-08	-3.1372E-17	2.1274E+01	7
10 years	-9.2235E-10	3.2024E-18	2.5557E+03	7
100 years	-5.4283E-15	3.4056E-23	1.0223E+02	7
1000 years	1.2081E-15	1.0598E-23	2.6407E+01	7
10^4 years	8.4265E-16	7.9954E-24	2.5142E+01	7

Shield

	a	b	Max. Error(%)	#Cases
WDR	4.0245E-17	3.4109E-24	1.3865E+00	6
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	3.0169E-11	-8.2165E-22	2.2445E+00	6
1 year	6.8336E-13	2.9077E-23	4.4225E-01	6
10 years	1.9636E-15	1.2645E-23	6.5991E+00	6
100 years	7.1244E-17	6.3246E-24	1.3248E+00	6
1000 years	5.2057E-19	3.4663E-25	1.8596E-01	6
10^4 years	7.7365E-22	3.0260E-25	2.4414E-03	6
Contact Dose Rate (mSv/hr)				
Shutdown	2.8362E-10	9.1568E-22	9.4102E-02	6
1 year	2.5866E-11	4.6396E-22	2.5361E-01	6
10 years	1.9144E-15	2.2254E-22	2.8384E+00	6
100 years	1.5534E-15	1.3176E-22	1.3827E+00	6
1000 years	1.1433E-17	1.0641E-24	1.2661E+00	6
10^4 years	4.1195E-22	9.3490E-26	1.2955E-03	6

B.4. Reference SiC/Li_2ZrO_3/He Design (R4)

First Wall / Divertor Wall

	a	b	Max. Error(%)	#Cases
WDR	-1.0494E-15	1.9424E-23	9.6754E+02	8
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	6.1494E-08	-4.5322E-19	2.6955E-01	8
1 year	6.3778E-13	6.3849E-21	1.1394E+01	8
10 years	1.5159E-13	1.6632E-21	1.3002E+01	8
100 years	-9.0719E-17	5.7867E-24	2.7871E+01	8
1000 years	-9.1672E-17	5.6685E-24	2.8701E+01	8
10^4 years	-9.1295E-17	5.0392E-24	3.3573E+01	8
Contact Dose Rate (mSv/hr)				
Shutdown	3.8512E-06	2.6571E-17	3.0990E-01	8
1 year	3.8967E-11	4.6691E-19	1.2371E+01	8
10 years	1.1905E-11	1.3847E-19	1.3427E+01	8
100 years	-9.3159E-15	1.7500E-22	8.2890E+02	8
1000 years	-9.3950E-15	1.7387E-22	9.6958E+02	8
10^4 years	-9.3139E-15	1.7237E-22	9.6959E+02	8

Divertor Plate

	a	b	Max. Error(%)	#Cases
WDR	-1.3874E-15	1.3675E-22	1.5389E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	4.2521E-07	4.3516E-17	8.2380E-01	7
1 year	1.1008E-09	2.1658E-17	1.1067E+01	7
10 years	2.9289E-10	9.5760E-18	8.0241E+00	7
100 years	1.0435E-11	2.2711E-18	1.8778E+00	7
1000 years	2.0506E-14	4.4723E-21	1.9031E+00	7
10^4 years	-2.0623E-17	5.6640E-24	6.1749E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	3.5243E-06	5.9008E-16	1.5158E+01	7
1 year	3.2255E-08	5.9272E-16	1.2949E+01	7
10 years	-2.9741E-09	3.1031E-16	6.0427E+01	7
100 years	4.0569E-14	4.9002E-21	6.6464E+00	7
1000 years	-3.9734E-16	9.9073E-23	1.5291E+00	7
10^4 years	-1.3910E-16	7.1542E-23	1.6893E+00	7

Blanket

	a	b	Max. Error(%)	#Cases
WDR	-2.1211E-15	4.4689E-23	3.7957E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	2.8331E-08	-1.8350E-18	5.6716E-01	7
1 year	3.2857E-11	5.4037E-21	1.0738E+01	7
10 years	2.4363E-12	1.1450E-20	2.2719E+01	7
100 years	1.9058E-13	9.2030E-21	4.5757E+00	7
1000 years	-5.0703E-14	3.1804E-21	5.4965E+00	7
10^4 years	-5.4101E-14	2.1895E-21	8.5876E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	2.1804E-06	1.0247E-16	4.4275E-01	7
1 year	5.5643E-10	-1.1786E-18	6.5560E+01	7
10 years	4.9896E-12	3.3844E-20	7.5289E+00	7
100 years	-7.1531E-16	1.2485E-23	5.3824E+01	7
1000 years	-6.8784E-16	1.1443E-23	4.6086E+01	7
10^4 years	-5.0833E-16	8.9108E-24	4.1482E+01	7

Vacuum Vessel

	a	b	Max. Error(%)	#Cases
WDR	-8.1228E-16	1.0022E-23	3.6356E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	3.4376E-07	-9.5952E-17	8.0425E+00	7
1 year	4.0652E-08	6.8884E-18	1.7016E+01	7
10 years	3.7067E-09	1.3540E-18	1.6154E+01	7
100 years	2.9015E-12	1.6775E-20	3.1964E+01	7
1000 years	4.1986E-14	6.3862E-22	2.5834E+01	7
10^4 years	2.9158E-14	4.3934E-22	2.9960E+01	7
Contact Dose Rate (mSv/hr)				
Shutdown	2.6233E-06	-1.5137E-15	1.9893E+01	7
1 year	4.3402E-08	-1.7874E-17	3.2995E+01	7
10 years	-4.1817E-09	1.4459E-17	3.0842E+03	7
100 years	-2.9075E-14	1.1407E-22	5.3707E+02	7
1000 years	1.1135E-15	9.3171E-24	2.8056E+01	7
10^4 years	7.9425E-16	7.0295E-24	2.7752E+01	7

Shield

	a	b	Max. Error(%)	#Cases
WDR	6.0900E-17	5.1591E-24	1.3846E+00	6
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	3.4547E-11	6.2648E-20	2.7717E+01	6
1 year	1.0348E-12	4.1116E-23	4.1717E-01	6
10 years	2.5434E-15	1.8476E-23	6.6123E+00	6
100 years	1.0779E-16	9.5095E-24	1.3318E+00	6
1000 years	7.8491E-19	4.6517E-25	2.0811E-01	6
10^4 years	-4.3092E-21	3.9861E-25	2.8970E-03	6
Contact Dose Rate (mSv/hr)				
Shutdown	2.8548E-10	6.5101E-19	1.3198E+01	6
1 year	3.9269E-11	6.9973E-22	2.8261E-01	6
10 years	3.8309E-15	3.3515E-22	4.1333E+00	6
100 years	2.3503E-15	1.9928E-22	1.3824E+00	6
1000 years	1.7299E-17	1.5923E-24	1.2801E+00	6
10^4 years	9.4136E-22	1.2441E-25	1.3895E-03	6

B.5. Variant $V/Li_2O/H_2O$ Design (V1)

First Wall / Divertor Wall

	a	b	Max. Error(%)	#Cases
WDR	3.0182E-17	1.7924E-24	1.7937E+01	8
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	1.9956E-07	-1.8810E-18	7.4617E-01	8
1 year	3.9657E-10	2.0639E-18	1.1859E+02	8
10 years	3.6784E-13	2.4825E-21	1.4197E+02	8
100 years	3.0086E-17	2.7091E-24	1.0712E+02	8
1000 years	2.5220E-18	4.0376E-25	8.2720E+00	8
10^4 years	4.3510E-18	2.4900E-25	1.8762E+01	8
Contact Dose Rate (mSv/hr)				
Shutdown	5.6096E-06	-2.5864E-16	1.9590E+00	8
1 year	8.4491E-10	2.0458E-19	8.5771E+00	8
10 years	1.2275E-15	3.2534E-23	1.3862E+02	8
100 years	3.2930E-16	1.3187E-23	7.3927E+00	8
1000 years	1.8080E-16	1.0427E-23	1.8664E+01	8
10^4 years	1.3119E-16	7.7017E-24	1.8427E+01	8

Divertor Plate

	a	b	Max. Error(%)	#Cases
WDR	-2.7018E-15	2.2992E-22	1.9144E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	6.5112E-07	6.7719E-17	8.6090E-01	7
1 year	1.6527E-09	3.2545E-17	1.1048E+01	7
10 years	4.5045E-10	1.4335E-17	8.1976E+00	7
100 years	1.8738E-11	3.3817E-18	2.7063E+00	7
1000 years	3.6863E-14	6.6586E-21	2.7365E+00	7
10^4 years	-2.8244E-17	7.9495E-24	6.0536E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	5.1173E-06	1.5015E-15	4.4541E+00	7
1 year	4.8825E-08	8.9184E-16	1.2884E+01	7
10 years	-9.1703E-09	5.1338E-16	7.1575E+01	7
100 years	3.9890E-14	8.2381E-21	8.7669E+00	7
1000 years	-6.3471E-16	1.4950E-22	3.0307E+00	7
10^4 years	-1.2266E-16	1.0197E-22	1.8308E+00	7

Blanket

	a	b	Max. Error(%)	#Cases
WDR	-8.2275E-17	2.5979E-24	1.1409E+01	7

Specific Actvity w/o Tritium (Ci/m^3)

Shutdown	7.5387E-08	4.6359E-18	6.2791E-01	7
1 year	2.1866E-10	-3.5442E-19	4.0542E+01	7
10 years	2.2658E-13	-3.9533E-22	5.1951E+01	7
100 years	1.2338E-16	6.0213E-25	2.2113E+01	7
1000 years	-1.4369E-17	4.9417E-25	1.0337E+01	7
10^4 years	-1.1874E-17	3.6727E-25	1.1628E+01	7

Contact Dose Rate (mSv/hr)

Shutdown	2.1598E-06	1.1851E-17	5.8493E+00	7
1 year	3.4360E-10	-6.4363E-20	2.0041E+00	7
10 years	1.4830E-15	8.0119E-24	2.1667E+01	7
100 years	-1.8269E-16	1.4372E-23	7.2445E+00	7
1000 years	-4.9627E-16	1.5355E-23	1.1619E+01	7
10^4 years	-3.6435E-16	1.1291E-23	1.1601E+01	7

Vacuum Vessel

	a	b	Max. Error(%)	#Cases
WDR	6.7390E-16	3.6678E-24	8.9521E+01	7

Specific Actvity w/o Tritium (Ci/m^3)

Shutdown	1.5655E-07	-6.4512E-17	1.2336E+01	7
1 year	2.6774E-08	6.2831E-18	1.4266E+01	7
10 years	2.3820E-09	7.0486E-19	1.7019E+01	7
100 years	1.7569E-13	1.7616E-21	2.4627E+01	7
1000 years	1.2239E-14	1.4102E-22	9.3269E+01	7
10^4 years	1.0799E-14	1.1598E-22	1.1626E+02	7

Contact Dose Rate (mSv/hr)

Shutdown	8.9017E-07	-2.2880E-16	1.2844E+01	7
1 year	3.7830E-08	2.5199E-18	4.5525E+01	7
10 years	-9.1844E-10	3.4395E-18	7.1293E+02	7
100 years	-4.8659E-15	2.9171E-23	1.1339E+02	7
1000 years	1.8396E-15	4.1816E-24	5.6626E+01	7
10^4 years	1.3549E-15	3.5385E-24	5.4078E+01	7

Shield

	a	b	Max. Error(%)	#Cases
WDR	3.6472E-17	3.0894E-24	1.3847E+00	6

Specific Actvity w/o Tritium (Ci/m^3)

Shutdown	2.3343E-11	-7.2600E-22	6.2163E+00	6
1 year	9.5961E-13	2.7300E-23	3.5782E-01	6
10 years	1.8056E-15	1.1178E-23	5.8827E+00	6
100 years	6.4436E-17	5.7038E-24	1.3277E+00	6
1000 years	4.6875E-19	2.9452E-25	1.9626E-01	6
10^4 years	-8.4157E-23	2.5464E-25	1.2682E-03	6

Contact Dose Rate (mSv/hr)

Shutdown	2.6981E-10	9.3088E-22	1.6565E-01	6
1 year	3.6574E-11	4.9037E-22	2.9241E-01	6
10 years	6.6565E-15	1.9590E-22	6.4158E+00	6
100 years	1.4076E-15	1.1934E-22	1.3834E+00	6
1000 years	1.0370E-17	9.5833E-25	1.2763E+00	6
10^4 years	2.1372E-21	7.9278E-26	4.2040E-03	6

B.6. Variant 316SS/Li_2O/H_2O Design (V2)

First Wall / Divertor Wall

	a	b	Max. Error(%)	#Cases
WDR	1.1262E-14	4.4029E-21	1.0764E+01	8

Specific Actvity w/o Tritium (Ci/m^3)

Shutdown	1.5142E-07	3.7698E-16	1.3663E+01	8
1 year	2.8390E-08	2.7666E-16	2.4515E+01	8
10 years	2.2147E-09	3.2882E-17	2.2895E+01	8
100 years	7.9929E-13	3.8520E-19	2.7663E+00	8
1000 years	2.5525E-14	1.8597E-20	5.9397E+00	8
10^4 years	1.6039E-14	6.2714E-21	1.1138E+01	8

Contact Dose Rate (mSv/hr)

Shutdown	1.7539E-06	3.4808E-16	6.5104E+00	8
1 year	7.7335E-08	1.1377E-15	4.3177E+00	8
10 years	1.1790E-08	3.1117E-16	1.2652E+01	8
100 years	8.7758E-14	3.8799E-21	6.7752E+00	8
1000 years	2.5416E-15	1.3517E-21	8.7336E+00	8
10^4 years	1.8073E-15	8.7615E-22	9.5158E+00	8

Divertor Plate

	a	b	Max. Error(%)	#Cases
WDR	-1.3223E-15	1.9550E-22	1.4001E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	6.1674E-07	6.0082E-17	9.8711E-01	7
1 year	1.4563E-09	2.7694E-17	1.1119E+01	7
10 years	3.8458E-10	1.2250E-17	8.2099E+00	7
100 years	1.7624E-11	2.9257E-18	3.8229E+00	7
1000 years	3.4613E-14	5.7613E-21	3.8346E+00	7
10^4 years	-2.2016E-17	6.9017E-24	6.1676E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	4.4606E-06	1.4584E-15	4.1006E+00	7
1 year	4.1664E-08	7.5585E-16	1.2432E+01	7
10 years	3.0828E-09	3.6801E-16	5.7267E+01	7
100 years	3.8889E-14	7.2855E-21	9.6038E+00	7
1000 years	-2.5220E-16	1.2610E-22	3.6343E+00	7
10^4 years	8.2592E-17	8.4255E-23	2.7983E+00	7

Blanket

	a	b	Max. Error(%)	#Cases
WDR	2.1388E-14	4.1682E-21	8.5633E+00	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	8.2599E-08	1.0213E-16	5.2972E+00	7
1 year	1.5635E-08	7.9067E-17	1.1974E+01	7
10 years	1.4115E-09	1.1434E-17	1.0552E+01	7
100 years	4.8210E-13	1.1947E-19	1.9656E+00	7
1000 years	2.6181E-14	8.0063E-21	6.1152E+00	7
10^4 years	1.7497E-14	2.5635E-21	1.1363E+01	7
Contact Dose Rate (mSv/hr)				
Shutdown	9.2175E-07	4.3604E-16	2.7722E+00	7
1 year	1.6985E-07	7.9106E-17	2.6751E+01	7
10 years	1.5130E-08	1.9140E-16	4.8387E+00	7
100 years	1.1209E-13	1.9940E-21	5.4096E+00	7
1000 years	2.7064E-15	5.1626E-22	9.0475E+00	7
10^4 years	1.9538E-15	3.4074E-22	9.6813E+00	7

<u>Vacuum Vessel</u>

	a	b	Max. Error(%)	#Cases
WDR	5.3072E-13	3.3580E-21	3.2239E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	8.0815E-08	9.9609E-18	5.9245E+00	7
1 year	2.1828E-08	8.0603E-18	1.9727E+01	7
10 years	3.4313E-09	1.9742E-18	2.6875E+01	7
100 years	1.1755E-11	2.5466E-19	1.0419E+01	7
1000 years	7.5257E-13	7.6210E-21	2.3030E+01	7
10^4 years	5.7325E-13	3.6281E-21	3.2197E+01	7
Contact Dose Rate (mSv/hr)				
Shutdown	1.1408E-06	-6.9685E-17	2.7702E+01	7
1 year	2.4881E-07	2.3743E-16	2.4142E+01	7
10 years	8.1000E-08	4.2078E-17	3.4150E+01	7
100 years	6.1034E-13	5.4875E-22	3.3141E+01	7
1000 years	2.3663E-14	2.0383E-22	2.6067E+01	7
10^4 years	1.7035E-14	1.3292E-22	2.7902E+01	7

<u>Shield</u>

	a	b	Max. Error(%)	#Cases
WDR	4.3846E-17	3.7150E-24	1.3825E+00	6
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	5.7902E-11	-6.9112E-21	5.8976E+01	6
1 year	1.3722E-12	3.8233E-23	3.6146E-01	6
10 years	2.6004E-15	1.4039E-23	6.1070E+00	6
100 years	7.7693E-17	6.9401E-24	1.3183E+00	6
1000 years	5.6510E-19	4.2255E-25	1.6802E-01	6
10^4 years	-5.9863E-22	3.7456E-25	2.7436E-03	6
Contact Dose Rate (mSv/hr)				
Shutdown	4.0597E-10	-2.2887E-23	3.3433E+00	6
1 year	5.2734E-11	7.0367E-22	2.8467E-01	6
10 years	8.6392E-15	2.3875E-22	8.7680E+00	6
100 years	1.7082E-15	1.4487E-22	1.3819E+00	6
1000 years	1.2582E-17	1.1850E-24	1.2539E+00	6
10^4 years	1.2015E-21	1.1765E-25	1.4566E-03	6

B.7. Variant PCA/Li_2O/H_2O Design (V3)

First Wall / Divertor Wall

	a	b	Max. Error(%)	#Cases
WDR	1.1648E-13	5.0207E-21	4.1826E+01	8
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	1.7570E-07	2.6884E-16	5.2513E+00	8
1 year	3.5826E-08	1.9341E-16	1.0453E+01	8
10 years	2.5467E-09	2.0629E-17	1.0730E+01	8
100 years	2.2656E-12	4.5428E-19	4.6019E+00	8
1000 years	1.1426E-13	1.8590E-20	1.0035E+01	8
10^4 years	7.5272E-14	6.9850E-21	1.4944E+01	8
Contact Dose Rate (mSv/hr)				
Shutdown	1.9289E-06	6.4222E-16	2.0125E+00	8
1 year	7.3833E-08	3.1059E-16	8.3334E+00	8
10 years	4.4662E-09	7.4156E-17	7.2644E+00	8
100 years	6.0567E-13	9.9613E-21	8.6232E+01	8
1000 years	6.9244E-14	4.6279E-21	3.1175E+01	8
10^4 years	2.4277E-14	3.0899E-21	1.1212E+01	8

Divertor Plate

	a	b	Max. Error(%)	#Cases
WDR	-9.5513E-15	2.4592E-22	3.4940E+02	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	6.1555E-07	4.9491E-17	6.2045E-01	7
1 year	1.3326E-09	2.7606E-17	1.0683E+01	7
10 years	3.7572E-10	1.2092E-17	7.8025E+00	7
100 years	1.2938E-11	2.8692E-18	2.1526E+00	7
1000 years	2.5181E-14	5.6511E-21	2.1707E+00	7
10^4 years	-1.8361E-16	7.4298E-24	8.0192E+01	7
Contact Dose Rate (mSv/hr)				
Shutdown	5.7491E-06	-6.2788E-15	3.4017E+01	7
1 year	4.0665E-08	7.5245E-16	1.2394E+01	7
10 years	3.8972E-09	3.8434E-16	6.6258E+01	7
100 years	-2.3509E-13	8.8935E-21	1.5125E+02	7
1000 years	-2.3567E-15	1.3760E-22	3.8190E+01	7
10^4 years	2.0051E-17	8.3703E-23	2.4140E+00	7

Blanket

	a	b	Max. Error(%)	#Cases
WDR	1.1273E-15	5.6683E-21	1.1965E+01	6
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	8.2139E-08	4.9974E-17	1.7091E+00	6
1 year	1.5075E-08	3.8964E-17	5.1499E+00	6
10 years	1.1225E-09	4.7149E-18	5.8916E+00	6
100 years	5.8964E-13	1.3955E-19	1.5253E+00	6
1000 years	2.0730E-15	7.6541E-21	3.5676E+00	6
10^4 years	2.8379E-15	3.0634E-21	4.7768E+00	6
Contact Dose Rate (mSv/hr)				
Shutdown	8.9959E-07	9.9885E-16	1.6751E+01	6
1 year	3.9370E-08	1.3364E-16	1.7226E+01	6
10 years	3.7247E-09	3.3269E-17	4.3424E+00	6
100 years	-1.4426E-12	2.4595E-20	6.0573E+01	6
1000 years	5.2658E-13	2.6876E-21	1.8433E+01	6
10^4 years	1.6162E-15	2.8676E-21	2.6953E+00	6

Vacuum Vessel

	a	b	Max. Error(%)	#Cases
WDR	2.3632E-12	1.3375E-21	6.3750E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	9.0577E-08	3.8752E-18	3.5264E+00	7
1 year	1.7714E-08	5.1503E-18	1.4025E+01	7
10 years	1.6882E-09	1.1763E-18	1.8964E+01	7
100 years	1.7490E-11	2.8906E-19	1.3041E+01	7
1000 years	1.2107E-12	7.6795E-21	3.0675E+01	7
10^4 years	7.9530E-13	3.8640E-21	3.7727E+01	7
Contact Dose Rate (mSv/hr)				
Shutdown	1.3475E-06	-3.4012E-16	2.0651E+01	7
1 year	6.6571E-08	2.4372E-17	1.8320E+01	7
10 years	1.2374E-08	8.5370E-18	3.1269E+01	7
100 years	1.8677E-11	-1.7396E-20	1.6788E+02	7
1000 years	1.3361E-12	2.4520E-21	4.9821E+01	7
10^4 years	3.3899E-13	2.5119E-21	2.8840E+01	7

Shield

	a	b	Max. Error(%)	#Cases
WDR	3.9136E-17	3.3167E-24	1.3845E+00	6
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	8.2098E-11	-6.9210E-20	9.7081E+01	6
1 year	1.1880E-12	3.5411E-23	3.7778E-01	6
10 years	2.5733E-15	1.2893E-23	6.3927E+00	6
100 years	6.9446E-17	6.2369E-24	1.3104E+00	6
1000 years	5.0294E-19	4.1297E-25	1.4931E-01	6
10^4 years	-1.3174E-21	3.7010E-25	1.4098E-03	6
Contact Dose Rate (mSv/hr)				
Shutdown	7.7765E-10	-6.9416E-19	7.6732E+01	6
1 year	4.5713E-11	6.1417E-22	2.8735E-01	6
10 years	7.6655E-15	2.1384E-22	7.7680E+00	6
100 years	1.5290E-15	1.2971E-22	1.3829E+00	6
1000 years	1.1259E-17	1.0731E-24	1.2393E+00	6
10^4 years	1.6308E-21	1.1740E-25	2.5199E-03	6

B.8. Variant VA64/Li_2O/H_2O Design (V4)

First Wall / Divertor Wall

	a	b	Max. Error(%)	#Cases
WDR	-6.1907E-16	3.2154E-20	8.8974E+00	8
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	2.6098E-07	4.7235E-16	1.2803E+01	8
1 year	3.3245E-08	3.3559E-16	3.0635E+01	8
10 years	1.9501E-09	3.1404E-17	3.0823E+01	8
100 years	1.3367E-13	6.1604E-20	3.6877E+00	8
1000 years	-6.0642E-16	2.9779E-20	2.4234E+00	8
10^4 years	-6.4650E-16	1.0535E-20	4.5785E+00	8
Contact Dose Rate (mSv/hr)				
Shutdown	4.3193E-06	1.1742E-15	2.4338E+00	8
1 year	1.6772E-07	5.6391E-16	2.6068E+01	8
10 years	1.1356E-09	3.4451E-17	1.4882E+01	8
100 years	-1.3240E-12	1.4794E-19	5.2402E+01	8
1000 years	-1.7298E-14	1.2772E-19	8.9585E+00	8
10^4 years	-1.2606E-14	9.3853E-20	8.9570E+00	8

Divertor Plate

	a	b	Max. Error(%)	#Cases
WDR	-2.1726E-15	2.3218E-22	1.4495E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	6.8674E-07	7.5146E-17	8.5974E-01	7
1 year	1.8690E-09	3.7274E-17	1.1098E+01	7
10 years	5.1830E-10	1.6289E-17	8.3330E+00	7
100 years	2.1750E-11	3.7843E-18	2.9031E+00	7
1000 years	4.2741E-14	7.4513E-21	2.9197E+00	7
10^4 years	-2.3920E-17	8.9130E-24	7.3089E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	5.1666E-06	7.6720E-15	2.6247E+01	7
1 year	5.5763E-08	1.0266E-15	1.2860E+01	7
10 years	-8.5869E-09	5.5550E-16	6.2621E+01	7
100 years	5.4261E-14	8.6003E-21	8.6018E+00	7
1000 years	-4.4864E-16	1.6078E-22	2.1858E+00	7
10^4 years	2.6844E-17	1.1314E-22	1.5514E+00	7

Blanket

	a	b	Max. Error(%)	#Cases
WDR	1.7856E-13	3.4179E-20	1.0545E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	1.2996E-07	1.4258E-16	8.2326E+00	7
1 year	1.2159E-08	1.0415E-16	2.7752E+01	7
10 years	6.8181E-10	1.0321E-17	2.8108E+01	7
100 years	1.1109E-13	3.6184E-20	2.9261E+00	7
1000 years	3.9606E-14	1.7231E-20	5.1241E+00	7
10^4 years	2.6091E-14	7.6456E-21	7.3384E+00	7
Contact Dose Rate (mSv/hr)				
Shutdown	2.3578E-06	4.8444E-16	9.2967E+00	7
1 year	7.1003E-08	2.1046E-16	1.9539E+01	7
10 years	9.6978E-10	2.3295E-17	1.0262E+01	7
100 years	-1.3345E-12	1.8618E-19	1.1806E+01	7
1000 years	7.1311E-13	1.3809E-19	1.0679E+01	7
10^4 years	5.2447E-13	1.0153E-19	1.0678E+01	7

Vacuum Vessel

	a	b	Max. Error(%)	#Cases
WDR	5.7071E-12	2.4432E-20	4.0607E+01	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	1.9348E-07	-5.3222E-18	2.4581E+00	7
1 year	1.8185E-08	4.6764E-18	1.4092E+01	7
10 years	1.6705E-09	8.2611E-19	1.9737E+01	7
100 years	2.4640E-12	3.7997E-20	1.3739E+01	7
1000 years	1.2810E-12	2.2423E-20	1.4826E+01	7
10^4 years	8.4585E-13	9.0404E-21	2.2052E+01	7
Contact Dose Rate (mSv/hr)				
Shutdown	3.8912E-06	1.9084E-16	7.8890E+00	7
1 year	8.2400E-08	6.0861E-18	1.5422E+01	7
10 years	1.1154E-08	2.1240E-18	3.9482E+01	7
100 years	2.3822E-11	1.0362E-19	4.0030E+01	7
1000 years	2.2811E-11	1.0055E-19	4.0104E+01	7
10^4 years	1.6770E-11	7.3938E-20	4.0105E+01	7

Shield

	a	b	Max. Error(%)	#Cases
WDR	4.8245E-17	2.6794E-24	3.2492E+00	7
Specific Actvity w/o Tritium (Ci/m^3)				
Shutdown	-2.3180E-10	7.7025E-19	8.4961E+02	7
1 year	1.0228E-12	1.8317E-23	5.0769E-01	7
10 years	2.1943E-15	9.6627E-24	9.9197E+00	7
100 years	8.5402E-17	5.0218E-24	3.0762E+00	7
1000 years	5.5886E-19	3.1742E-25	3.1473E-01	7
10^4 years	2.8202E-21	2.8261E-25	3.9624E-03	7
Contact Dose Rate (mSv/hr)				
Shutdown	-5.9591E-09	1.8676E-17	1.7754E+03	7
1 year	4.0020E-11	2.4457E-22	3.5925E-01	7
10 years	7.7520E-15	1.7546E-22	8.7612E+00	7
100 years	1.9196E-15	1.0671E-22	3.2473E+00	7
1000 years	1.4146E-17	8.7671E-25	2.9370E+00	7
10^4 years	6.4688E-21	9.0508E-26	2.2338E-02	7

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