TRITIUM BREEDING AND ACTIVATION IN THE CASCADE REACTOR*

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Abstract

Cascade is an inertial fusion reactor that uses circulating Li_2O pellets as a coolant and tritium breeding medium. The pellets flow through a horizontal rotating vessel, and they are held against the vessel wall by centrifugal force. Three wall designs were considered: a steel shell and a SiC shell prestressed by Al or steel cables. The nuclear heating, tritium breeding ratio, afterheat, inhalation biological hazard potential, and shallow land burial index were calculated for each configuration. Tritium breeding is more than adequate (1.35). Spray cooling of the wall exterior will be required during operation, but thermal radiation heat removal will be sufficient after shutdown. Allowable release fractions during an accident are higher than in comparable designs. Disposal of activated components by shallow land burial is feasible. Hands-on maintenance of the SiC/Al wall will be possible if it is moved away from the reflector.

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Introduction

Cascade is an inertial fusion reactor that uses high temperature Li_2O as a coolant and tritium breeding material. About 100 m^3 of fine Li_2O pellets flow through a horizontally rotating vessel. Centrifugal force from the 30 rpm spin holds the particles against the wall which is $\sim 1 \text{ m}$ in radius at the pole (Li_2O and laser inlets) and $\sim 4.4 \text{ m}$ in radius at the equator (Li_2O outlet). Cascade is described in more detail in references [1] and [2].

In this paper, neutronic and activation calculations for the Cascade reactor are described. Three wall configurations were investigated. In the first, a 2.75 cm thick 2-1/4 Cr-1 Mo steel wall was used. In the second, a 2.75 cm thick SiC wall was prestressed with Al cables, modeled as an outer 1.5 cm thick shell. In the final configuration, the prestressing cables were 2-1/4 Cr-1 Mo steel.

The basic steel wall was the initial choice. [1] However, heating from the hot Li_2O and from the neutrons was at a level that required spray cooling of the outer wall surface. The SiC wall was proposed since it can run hot, allowing adequate heat removal by radiation to the reflector. The prestressing cables would be insulated from the SiC such that only their internal neutron heating would be removed by radiation. Since Al cables must operate at a lower temperature than steel, the design problem is most difficult for Al cables. The neutronics and activation calculations in this paper serve as input to the wall thermal-mechanical design.

Neutronic Model

The Cascade chamber was modeled as shown in Figure 1. The equatorial plane was taken as a reflecting boundary. The compressed fusion fuel and pusher regions were included. The Li_2O thickness at the midplane was 96 cm, with an average density 1.0365 g/cc (50% of the theoretical value). The wall was modeled as a series of cones. Neutron leakage through the beam port, the reflector, and the corner between them was monitored. Since an earlier, unreflected, neutronics calculation showed considerable neutron leakage, a canned graphite reflector was included in these calculations.

The compositions of all the materials are shown in Table 1. Care was taken to include impurities since their activation sometimes dominates. However, the 0.25 appm U and 0.05 appm Th impurities in SiC were ignored; their importance will be explored at a later date.

The neutronics calculation was performed using the ALICE [3] three-dimensional, continuous-energy, Monte-Carlo, neutron-photon transport code. ALICE is a modification of TART [4] that treats the resonance region in more detail. The calculations used 18000 neutron histories and produced reasonable standard deviations (fraction to few % in Li_2O regions, few to few tens of % in wall regions).

Neutronic Results

The calculated results for the three wall configurations are shown in Table 2. The fusion multiplication factor of 1.11 to 1.12 is low compared to other ICF reactors (1.26 in Pulse-Star, 1.185 in HYLIFE).

Fig. 1 Cascade neutronics model. The Li_2O and wall rotate; the reflector is stationary.

Table 1. Material compositions. Parenthetical values are ppm. The Li is natural (7.5% ⁶Li). The canned graphite neglects some of the steel impurities.

		2-1/4 Cr -			Canned	
Z	Element	Li ₂ O*	1 Mo Steel**	SiC*	Al*	Graphite**
3	Li	99.9524				
6	C		0.11	49.99961		79.8398
11	Na			(0.05)		
13	Al				99.995	
14	Si		0.2	49.99961		0.1091
15	P		(110)			
16	S		(220)			
20	Ca	(400)				
23	V		(50)			
24	Cr		2.33			0.4541
25	Mn	(4)	0.36	(0.03)		(908)
26	Fe	(20)	95.463	(7.7)	(30)	19.3044
27	Co		(20)	(0.21)		
28	Ni		0.19			
29	Cu	(10)	0.27		(20)	
33	As		(60)	(0.003)		
41	Nb		(80)			
42	Mo	(2)	1.01			0.2018
50	Sn	(40)	(110)			
51	Sb		(20)			
74	W			(0.015)		

* atomic %

** wt %

Table 2. Neutronic results. The Li_2O energy includes the α and target-neutron interaction energies. The ports represent 0.78% of the reactor area.

	<u>Steel</u>	<u>SiC/Al</u>	<u>SiC/Steel</u>
<u>Energy Deposition (MeV)</u>			
Li_2O	19.41	19.35	19.41
wall	0.083	0.037	0.035
backing	--	0.013	0.039
reflector	<u>0.126</u>	<u>0.130</u>	<u>0.117</u>
total	19.62	19.53	19.60
<u>Multiplication</u>			
$E_{\text{Li}_2\text{O}}/E_{\text{fusion}}$	1.104	1.101	1.104
$E_{\text{thermal}}/E_{\text{fusion}}$	1.116	1.111	1.115
<u>Energy Leakage (MeV)</u>			
port	0.115	0.113	0.107
corner	0.032	0.073	0.067
reflector	<u>0.062</u>	<u>0.015</u>	<u>0.016</u>
total	0.208	0.200	0.190
<u>Neutron Leakage (%)</u>			
port	2.12	2.04	1.76
corner	2.96	2.99	2.74
radial	<u>0.42</u>	<u>0.29</u>	<u>0.31</u>
total	5.50	5.32	4.81
<u>Tritium breeding ratio</u>			
ratio	1.34	1.36	1.35

For the same recirculating power, the low multiplier must be compensated by increased driver efficiency, thermal efficiency, or target gain. Fortunately, the high Cascade Li_2O temperature offers a chance for high thermal efficiency.

If the wall and reflector energy is recovered at low temperature, the effective multiplication factor falls further. The Li_2O /fusion ratio of 1.10 approximates the revised value. However, the actual effective multiplier depends on the high and low temperature thermal efficiencies, and on the amount of Li_2O energy that leaks through the wall. The equatorial Li_2O region was zoned radially (a 1 cm thick inner zone followed by three equally thick zones). The energy deposition profile is shown in Figure 2. The neutron energy leakage is about 1% of the thermal energy, with most of the loss in the port area (including the corner). About 5% of the neutrons leak, i.e. about six times the port surface area fraction. The leakage through the ports themselves is ~2%, or about three times the port area.

The tritium breeding ratio is a healthy 1.35 for all three configurations.

The wall/cable heating is 14.4, 8.5, and 12.6 MW_t , respectively, for the three configurations, assuming a 3000 MW_t power. These levels preclude radiation cooling of the basic steel wall, even if heat transport from the Li_2O could be prevented. For the SiC (~6 MW_t), radiation cooling is feasible since the allowable temperature is higher. However, neutron heating of the low temperature Al cables is enough (2.2 MW_t) to preclude radiation cooling, even with perfect insulation between the Al and SiC. For the mid-temperature steel cables, the

Fig. 2 Energy deposition profile in the Cascade equatorial Li_2O .

neutron heating (6.7 MW_t) is borderline. With superb insulation from the SiC and careful attention to emissivity maximization, the steel cable design might be radiation cooled. However, it is prudent to continue to base the design on spray cooling, since only one configuration is even marginal for radiation cooling.

Activation

The ALICE energy dependent fluxes were used to energy-average the ACTL cross section library [3] for each spatial region using the ORLIB code. [5] The Li_2O zones were also spatially averaged since mixing will eliminate any spatial flux distribution effects. The wall zones were also spatially averaged since they have similar neutron spectral shapes. The cross sections were used in the FORIG code [6] to determine activity as a function of time. Thirty years of flux at 3000 MW_t and 70% capacity factor were assumed.

Activation of the Li_2O , steel, SiC, Al, and reflector are shown in Table 3 at various times during and after operation. During operation, the Li_2O (^{16}N) dominates the activity for all three configurations. After shutdown, the reflector and wall steel (^{55}Fe) quickly take over. After several decades, ^{14}C in the Li_2O and ^{93}Mo in the reflector and steel dominate. All three configurations have similar activities (within a factor of 2) at all times during and after shutdown.

The activity has plateaus in the day-to-month and 50-to-500 year time frames. Thus, if the reactor has safety or maintenance problems at one day after shutdown, waiting an additional month probably won't help. Also, if the components are not cheaply disposable at 50 years after

Table 3. Activation (kCi). The principal contributor is also shown for each entry.

	Time	1 mo	Operation 5 yr	30 yr	1 day	1 mo	After Shutdown 10 yr	50 yr	500 yr	3000 yr
<u>Steel</u>	L120	2.21E5 16N	2.02E5 16N	1.83E5 16N	636 37Ar	170 37Ar	8.9 14C	6.3 14C	4.7 14C	3.2 14C
	Steel	1.05E4 56Mn	1.54E4 56Mn	1.72E4 56Mn	8530 55Fe	6250 55Fe	393 55Fe	8 63Ni	4 93Mo	2 93Mo
	Reflector	6580 56Mn	1.04E4 56Mn	1.11E4 55Fe	5800 55Fe	5030 55Fe	350 55Fe	1.7 93Mo	1.6 93Mo	0.89 93Mo
	Total	2.38E5	2.28E5	2.11E5	1.50E4	1.15E4	752	16	10	6
<u>SIC/A1</u>	L120	2.23E5 16N	2.11E5 16N	1.83E5 16N	796 37Ar	443 37Ar	9 14C	6 14C	5 14C	3 14C
	SIC	2210 28Al	2210 28Al	2210 28Al	0.73 60Co	0.34 60Co	0.075 60Co	0.002 14C	0.0017 14C	0.0013 14C
	A1	6990 28Al	6990 28Al	6980 28Al	170 24Na	0.58 55Fe	0.005 55Fe	0.013 63Ni	2.4E-4 26Al	2.0E-4 26Al
	Reflector	5050 56Mn	9210 56Mn	1.09E4 55Fe	6220 55Fe	5350 55Fe	344 55Fe	1.8 93Mo	1.6 93Mo	0.9 93Mo
	Total	2.37E5	2.29E5	2.03E5	7190	5790	353	8	7	4
<u>SIC/Steel</u>	L120	2.25E5 16N	2.13E5 16N	1.84E5 16N	798 37Ar	444 37Ar	8.9 14C	6.4 14C	4.7 14C	3.2 14C
	SIC	1800 28Al	1800 28Al	1800 28Al	0.65 60Co	0.31 60Co	0.07 60Co	0.0018 14C	0.0014 14C	0.0011 14C
	Steel	5920 56Mn	9250 56Mn	1.06E4 55Fe	5620 55Fe	4300 55Fe	290 55Fe	5.5 63Ni	2.5 93Mo	1.4 93Mo
	Reflector	5110 56Mn	9450 56Mn	1.12E4 55Fe	6470 55Fe	5590 55Fe	362 55Fe	1.8 93Mo	1.6 93Mo	0.9 93Mo
	Total	2.38E5	2.33E5	2.08E5	1.29E4	1.03E4	661	13.7	8.8	5.5

shutdown, waiting centuries probably won't help. These issues are further explored below, using the afterheat, inhalation biological hazard potential (bhp), surface gamma dose rate, and shallow burial index as figures of merit. These figures of merit are discussed in more detail in references [7] and [8].

Afterheat is important shortly after shutdown; thus, the shutdown and one day results are most significant. These and other values are shown in Table 4. Decay heat at shutdown is ~ 8 MW, and it quickly drops after shutdown. At 1 day, it is in the 11-19 kW range; the detailed output indicates that most of the decrease is in the first minute after shutdown. Since thermal radiation can remove a few MW, the decay heat can be removed easily by thermal radiation with no active cooling systems. However, the heat transport from the Li_2O through the wall could be much more significant. A preliminary calculation [9] indicates that thermal radiation can also remove this heat.

Surface dose rate is important at times at which maintenance could be performed; thus, the one day and one month results are most significant (Table 5). Levels above ~ 100 R/hr probably preclude hands-on maintenance. The Li_2O must be drained before maintenance begins due to its activity. The steel wall, steel cables, and reflectors all require remote maintenance. The SiC/Al wall could be maintained using hands-on techniques if it is removed from the surrounding reflector region.

The inhalation bhp is the volume of air required to dilute vaporized material to breathing standards. If the plume occupies some tens of km^3 , then Table 6 shows that, at one day after shutdown, release of $\sim 10^{-5}$ of the reflector, steel wall, or cable steel would be

Table 4. Decay heat (kW) for the Cascade components.

	Time	1 mo	Operation 5 yr	30 yr	1 day	1 mo	After Shutdown		500 yr	3000 yr
							10 yr	50 yr		
<u>Steel</u>	L120	8220 16N	7960 16N	7620 16N	0.2 122Sb	0.13 54Mn	0.011 60Co	0.005 39Ar	0.002 14C	0.001 14C
	Steel	106 56Mn	114 56Mn	118 56Mn	13.8 54Mn	8.2 54Mn	0.60 60Co	0.005 60Co	0.001 94Nb	7E-4 94Nb
	Reflector	70 56Mn	73.2 56Mn	78.4 56Fe	4.8 54Mn	3.3 54Mn	0.24 60Co	6E-4 60Co	2E-4 93Nb ^m	1E-4 93Nb ^m
	Total	8400	8150	7820	18.8	11.6	0.85	0.011	0.003	0.0018
<u>SiC/Al</u>	L120	8260 16N	8100 16N	7630 16N	0.39 122Sb	0.17 54Mn	0.011 60Co	0.005 39Ar	0.002 14C	0.001 14C
	SiC	37.7 28Al	37.7 28Al	37.7 28Al	0.007 60Co	0.005 60Co	0.0011 60Co	6E-6 60Co	7E-7 14C	6E-7 14C
	Al	125 28Al	125 28Al	125 28Al	4.7 24Na	1.0E-4 65Zr	1.2E-5 60Co	4E-6 26Al	3.9E-6 26Al	3.7E-6 26Al
	Reflector	65.7 56Mn	69.1 56Mn	75.5 56Mn	6 54Mn	4 54Mn	0.29 60Co	0.0017 60Co	2.2E-4 93Nb ^m	1.3E-4 93Nb ^m
	Total	8490	8330	7870	11.1	4.2	0.30	0.007	0.002	0.001
<u>SiC/Steel</u>	L120	8340 16N	8180 16N	7690 16N	0.39 122Sb	0.17 54Mn	0.011 60Co	0.005 39Ar	0.002 14C	0.001 14C
	SiC	30.7 28Al	30.7 28Al	30.7 28Al	0.006 60Co	0.004 60Co	0.0010 60Co	6E-6 60Co	6E-7 14C	5E-7 14C
	Steel	59.3 56Mn	62.9 56Mn	67.5 56Mn	7.8 60Co	4.6 60Co	0.48 60Co	0.004 60Co	6E-4 93Nb ^m	4E-4 94Nb
	Reflector	66.6 56Mn	70.0 56Mn	76.9 56Mn	6.0 54Mn	4.2 54Mn	0.30 60Co	0.0017 60Co	2E-4 93Nb ^m	1E-4 93Nb ^m
	Total	8500	8340	7870	14.3	9.0	0.8	0.011	0.003	0.0015

Table 5. Surface dose rate (R/hr) for Cascade components. No totals are shown since mutual shielding precludes simultaneous exposure to all components. The one day and one month values are the most significant.

	Time	1 mo	Operation 5 yr	30 yr	1 day	1 mo	After Shutdown 10 yr	50 yr	500 yr	3000 yr
<u>Steel</u>	L12O	7.35E6 16N	7.30E6 16N	7.05E6 16N	324 54Mn	185 54Mn	7.3 60Co	0.034 60Co	8.9E-4 94Nb	8.3E-4 94Nb
	Steel	2.03E5 56Mn	2.17E5 56Mn	2.22E5 56Mn	2.54E4 54Mn	1.98E4 54Mn	1770 60Co	10 60Co	0.9 94Nb	0.8 94Nb
	Reflector	7.59E4 56Mn	8.04E4 56Mn	8.74E4 56Mn	7170 54Mn	6120 54Mn	434 60Co	2.26 60Co	0.010 94Nb	0.009 94Nb
<u>S1C/A1</u>	L12O	7.35E6 16N	7.30E6 16N	7.05E6 16N	328 54Mn	186 54Mn	7 60Co	0.03 60Co	9E-4 94Nb	8E-4 94Nb
	S1C	7.54E4 28A1	7.54E4 28A1	7.54E4 28A1	15 60Co	14 60Co	4 60Co	0.02 60Co	3E-7 26A1	3E-7 26A1
	A1	2.79E5 28A1	2.79E5 28A1	2.78E5 28A1	1.41E4 24Na	0.33 65Zn	0.041 60Co	0.012 26A1	0.012 26A1	0.012 26A1
	Reflector	7.71E4 56Mn	8.08E4 56Mn	8.75E4 56Mn	6860 54Mn	5850 54Mn	528 60Co	2.7 60Co	0.008 94Nb	0.007 94Nb
<u>S1C/Steel</u>	L12O	7.42E6 16N	7.37E6 16N	7.12E6 16N	330 54Mn	187 54Mn	7 60Co	0.034 60Co	9.2E-4 94Nb	8.5E-4 94Nb
	S1C	6.12E4 28A1	6.12E4 28A1	6.12E4 28A1	14 60Co	13 60Co	4 60Co	0.019 60Co	3.2E-8 26A1	3.2E-8 26A1
	Steel	1.26E5 56Mn	1.32E5 56Mn	1.39E5 56Mn	1.55E4 60Co	1.19E4 60Co	1580 60Co	8.7 60Co	0.53 94Nb	0.49 94Nb
	Reflector	7.81E4 56Mn	8.17E4 56Mn	8.90E4 56Mn	6720 54Mn	5720 54Mn	547 60Co	2.8 60Co	0.008 94Nb	0.007 94Nb

Table 6. Inhalation bhp (km^3) for Cascade components The 1 day value is most significant.

	Time	1 mo	Operation 5 yr	30 yr	1 day	1 mo	After Shutdown 10 yr	50 yr	500 yr	3000 yr
<u>Steel</u>	L1 ₂ O	7.75E6 16 _N	7.74E6 16 _N	6.50E6 16 _N	1.55E5 121 _{Sn}	1.06E5 123 _{Sn}	1.46E4 39 _{Ar}	1.17E4 39 _{Ar}	4410 39 _{Ar}	1090 10 _{Be}
	Steel	7.55E5 56 _{Mn}	1.92E6 54 _{Mn}	2.31E6 54 _{Mn}	1.87E6 54 _{Mn}	1.57E6 54 _{Mn}	1.64E5 60 _{Co}	2.59E4 93 _{Mo}	2.13E4 93 _{Mo}	1.20E4 93 _{Mo}
	Reflector	6.36E5 56 _{Mn}	1.02E6 54 _{Mn}	1.21E6 54 _{Mn}	9.12E5 54 _{Mn}	7.60E5 54 _{Mn}	6.91E4 60 _{Co}	9490 93 _{Mo}	8510 93 _{Mo}	4780 93 _{Mo}
	Total	9.14E7	1.01E7	10.0E7	2.94E6	2.44E6	2.48E5	4.71E4	3.42E4	1.79E4
<u>SiC/A1</u>	L1 ₂ O	7.75E6 16 _N	7.47E6 16 _N	6.51E6 16 _N	3.16E5 121 _{Sn}	1.37E5 123 _{Sn}	1.46E4 39 _{Ar}	1.20E4 39 _{Ar}	4410 39 _{Ar}	1090 10 _{Be}
	SiC	7.58E4 28 _{A1}	7.64E4 28 _{A1}	7.67E4 28 _{A1}	1010 60 _{Co}	913 60 _{Co}	241 60 _{Co}	3.6 10 _{Be}	2.4 10 _{Be}	2.4 10 _{Be}
	A1	3.19E5 28 _{A1}	3.19E5 28 _{A1}	3.19E5 28 _{A1}	3.40E4 24 _{Na}	19.8 60 _{Co}	4.5 26 _{A1}	2.6 26 _{A1}	2.0 26 _{A1}	2.0 26 _{A1}
	Reflector	3.13E5 56 _{Mn}	8.85E5 54 _{Mn}	1.18E6 54 _{Mn}	9.46E5 54 _{Mn}	8.36E5 54 _{Mn}	7.93E4 60 _{Co}	9870 93 _{Mo}	8620 93 _{Mo}	4830 93 _{Mo}
	Total	8.46E6	8.75E6	8.09E6	1.30E6	9.74E5	9.41E4	2.19E4	1.30E4	5920
<u>SiC/Steel</u>	L1 ₂ O	7.81E6 16 _N	7.52E6 16 _N	6.57E6 16 _N	3.19E5 121 _{Sn}	1.38E5 123 _{Sn}	1.46E4 39 _{Ar}	1.21E4 39 _{Ar}	4430 39 _{Ar}	1090 10 _{Be}
	SiC	6.20E4 28 _{A1}	6.27E4 28 _{A1}	6.30E4 28 _{A1}	934 60 _{Co}	850 60 _{Co}	225 60 _{Co}	3.0 10 _{Be}	1.88 10 _{Be}	1.87 10 _{Be}
	Steel	4.21E5 56 _{Mn}	9.99E5 54 _{Mn}	1.30E6 60 _{Co}	1.05E6 60 _{Co}	8.89E5 60 _{Co}	1.26E5 60 _{Co}	1.65E4 93 _{Mo}	1.33E4 93 _{Mo}	7460 93 _{Mo}
	Reflector	3.15E5 56 _{Mn}	8.73E5 54 _{Mn}	1.18E6 54 _{Mn}	9.43E5 54 _{Mn}	8.34E5 54 _{Mn}	8.20E4 60 _{Co}	9760 93 _{Mo}	8520 93 _{Mo}	4780 93 _{Mo}
	Total	8.61E6	9.45E6	9.11E6	2.31E6	1.86E6	2.23E5	3.84E4	2.63E4	1.33E4

tolerable. This is a factor of 10-100 better than some other ICF designs. [10] A release of about 10^{-4} of the Li_2O would also be tolerable, as would 10^{-3} of the Al cables, or 1% of the SiC. Of course, the release fraction is scenario and nuclide dependent, and thus these estimates are overly simple.

The shallow burial index (SBI) was calculated for each component (Table 7) by summing the ratios of the specific activities (Ci/m^3) to the 10CFR61 limits. [11] The totals for the reactor used the total activity and total material volume to compute the specific activity for each nuclide. Thus, they were much less than the arithmetic sum of the components. The Li_2O and reflector could be buried separately in all three cases, as could the SiC and the Al cables. The steel wall and the steel cables cannot be buried alone. However, if they are buried as a unit with the Li_2O and reflector, only minor dilution is required for legal burial. This dilution could be easily accomplished by including elements of the biological shield that surrounds the reactor. Addition of limits for other nuclides (like ^{93}Mo) would increase the SBI, however, we believe shallow burial still is feasible.

In Reference [8], the author proposed an increase in the 0.2 Ci/m^3 ^{94}Nb limit since that limit was set by assuming no surviving barriers coupled with construction of homes in the (unrecognized) waste. If the proposed limit of 1100 is used, all three configurations could be buried with no dilution.

Summary

Cascade is a viable reactor concept from the viewpoints of tritium breeding and activation. Spray cooling of the rotating vessel will

Table 7. Shallow burial index, at 50 years after shutdown. Only nuclides listed in 10CFR61 were considered. A value below 1.0 allows legal burial.

	^{14}C	^{63}Ni	^{94}Nb	^{99}Tc	Total
<u>Steel</u>					
Li_2O	0.513	0.011	0.0028	$4.6\text{E}-4$	0.527
Steel	--	1.44	43.9	5.1	50.5
Reflector	0.0065	$2\text{E}-7$	0.086	0.136	0.228
Total	0.387	0.0435	1.096	0.156	1.682
<u>SiC/Al</u>					
Li_2O	0.511	0.012	0.0029	$4.7\text{E}-4$	0.525
SiC	0.0053	--	--	--	0.0053
Al	--	$8.2\text{E}-4$	--	--	$8.2\text{E}-4$
Reflector	0.0073	--	0.067	0.149	0.22
Total	0.389	0.0089	0.017	0.033	0.440
<u>SiC/Steel</u>					
Li_2O	0.513	0.011	0.0029	$4.7\text{E}-4$	0.527
SiC	0.0044	--	--	--	0.0044
Steel	--	1.99	41.05	4.25	47.2
Reflector	0.0076	--	0.068	0.143	0.218
Total	0.382	0.0346	0.562	0.088	1.067

probably be required during operation, but decay heat can be removed by radiation alone after shutdown. The allowable release fraction during an accident is considerably higher than in other designs. Remote maintenance will be required for steel walls, walls using steel prestressing cables, and the reflector. However, hands-on maintenance of a SiC/Al wall would be feasible after the wall is moved away from the reflector; this is the first fusion reactor with a hands-on maintainable first wall. Finally, disposal of the activated components by shallow land burial will be feasible.

References

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