

# 가 AMBIDEXTER

## Effects of Natural Uranium Denaturant on the Self-Sustainability of the AMBIDEXTER Reactor

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5

$^{232}\text{Th}/^{233}\text{U}$  AMBIDEXTER  
 $^{233}\text{U}$   
 AMBIDEXTER  
 가 ORIGEN2-HELIOS , ORIGEN2  
 AMBIDEXTER (30 )  
 . 3% AMBIDEXTER  
 $^{233}\text{U}$  58%  $^{238}\text{U}$   
 Pu 가

### Abstract

A denatured AMBIDEXTER fuel system, originally designed with the genuine  $^{232}\text{Th}/^{233}\text{U}$  fuel cycle, but modified by adding amount of natural uranium denaturant was evaluated to ensure its non-proliferation properties. We improved nuclear data libraries built in the ORIGEN2-HELIOS code system accurately enough to deal with the graphite-moderated molten salt reactor core. To confirm that the nuclear self-sustainability of the AMBIDEXTER should be intact, system performance was simulated for lifetime-equivalent operation time, 30 year. The model included the on-line reprocess and reinsertion options of ORIGEN2.

Simulations showed that the denatured AMBIDEXTER core could save 58% of  $^{233}\text{U}$  inventory required for initial loading period, compared with the pure thorium fuel cycle. And we confirmed that Pu isotope that is converted from  $^{238}\text{U}$  extracting was not permitted to system normal operation.

1.

가  $^{235}\text{U}/^{238}\text{U}$  가  
가 .  
 ,  $^{232}\text{Th}/^{233}\text{U}$   
AMBIDEXTER 가 .  
1 AMBIDEXTER , /  
 , /  
가  
 .  
AMBIDEXTER  
 ,  
 ,  
AMBIDEXTER  
 $\text{LiF-BeF}_2\text{-ThF}_4\text{-UF}_4$  가  
 $^{232}\text{Th}$   $^{233}\text{U}$   
 .  
- 가  
HELIOS-ORIGEN2  
가 .  
AMBIDEXTER  
 $^{238}\text{U}$   
가 Pu

## 2. AMBIDEXTER

### 2.1 AMBIDEXTER

#### AMBIDEXTER

가

1.  $^{233}\text{U}$  U 12%

2.  $\text{ThF}_4 + \text{UF}_4$  14%

가 1,  $^{233}\text{U}$  가  
2, 500°C

AMBIDEXTER가 가

가

1 가  $\text{UF}_4$  U 가  
5%

$\text{LiF}-\text{BeF}_2-\text{ThF}_4-\text{UF}_4$  70-16-

11-3 가  $^{233}\text{U}$  U  
10.75% 가

1000

$^{233}\text{U}$  가 2 가 가  
 $^{233}\text{U}$  2

24.3% 가 6.6% 가  $^{233}\text{U}$

2.27% 가 가

가  $^{233}\text{U}$

-Li, Be, F

가

3

2

$^{233}\text{U}$

$^{238}\text{U}$

$^{239}\text{Pu}$

## 2.2

## AMBIDEXTER

PWR

ORIGEN2

AMBIDEXTER

가

가

가

100

가

가

가

, AMBIDEXTER

가

ORIGEN

99.94%

HELIOS

AMBIDEXTER

가

4

$^{232}\text{Th}/^{233}\text{U}$

AMBIDEXTER

가

AMBIDEXTER가 가

(Blanket Full)

$^{232}\text{Th}/^{233}\text{U}$

0.75cm

(Seed)

가

3

AMBIDEXTER가 가

, 77

HELIOS

20MeV,

$10^{-5}\text{eV}$

4, 5

4

가

5

100KeV,

0.1eV

ORIGEN

가

AMBIDEXTER

가

4 5

, 77

3

PWR

6, 7, 8

<sup>151</sup>Sm

<sup>143</sup>Nd

PWR

AMBIDEXTER가 가

AMBIDEXTER

Pu

가

3

77

가

Be, F가

가

, Be

가

가

PWR

2.3

AMBIDEXTER

HELIOS

가

AMBIDEXTER

AMBIDEXTER

11

60%

가

, 10<sup>7</sup>

가

가

가

<sup>233</sup>U

6

58%

가

가가

가

$^{239}\text{Pu}$  가 12, 13  
 $^{233}\text{U}$  80% 가 ,  $10^6$   $^{233}\text{U}$  55%,  
 $^{239}\text{Pu}$ 가 30% 가  $^{232}\text{Th}$   
 가 55% 가 .

AMBIDEXTER

7  
 $^{233}\text{U}$  4.5%  
 Pu  
 15 Pu  
 $^{233}\text{U}$  Pu  
 Pu 16  
 , Pu  
 Pu  
 가 ,  
 가 ,  $^{239}\text{Pu}$   
 가 가 .

3.

$^{232}\text{Th}/^{233}\text{U}$  AMBIDEXTER  
 $^{233}\text{U}$  가  
 가 PWR  
 AMBIDEXTER  
 AMBIDEXTER  
 (30 )

$\text{LiF}-\text{BeF}_2-\text{ThF}_4-\text{UF}_4$  ,  
 70-16-11-3 가  $^{233}\text{U}$   
 $\text{U}$  10.75%  
 , 77 AMBIDEXTER  
 가 Pu  
 가 가 .

가 ,  
 $^{232}\text{Th}/^{233}\text{U}$

Pu 가 ,  
가 .

4.

가 , 가  
AMBIDEXTER

5.

2000

- [1] , , “ /  
” , 97 , , 1998
- [2] , , “AMBIDEXTER  
” , 98 , , 1999
- [3] , , “  
(1)- ” , , 2000
- [4] , “SAMS : 가  
” , , 1999
- [5] , “AMBIDEXTER ”,  
 , 1999
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 , 1999
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National Laboratory, ORNL/TM-7175, 1980

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2000

[ 1] 가

Fuel Composition LiF-BeF <sub>2</sub> -ThF <sub>4</sub> -UF <sub>4</sub>	<sup>233</sup> U enrich	Mole% of ThF <sub>4</sub> +UF <sub>4</sub>	Initial K <sub>eff</sub>
70.2-16-11-2.8	9.00%	13.80%	0.92377
	10.00%	13.80%	0.97522
70.0-16-11-3.0	10.00%	14.00%	1.00294
	10.50%	14.00%	1.02773
	10.75%	14.00%	1.03967
	11.00%	14.00%	1.05144

[ 2] <sup>233</sup>U

Time	1.0D	10.0D	50.0D	100.0D	500.0D	1000.0D
K <sub>eff</sub>	1.03967	1.04071	1.0525	1.06735	1.14744	1.21322
NP	7.850E+04	7.870E+04	8.040E+04	8.220E+04	9.150E+04	9.760E+04
ND	7.550E+04	7.570E+04	7.640E+04	7.700E+04	7.970E+04	8.050E+04
U233 enrich	10.75 %	10.76 %	10.83 %	10.92 %	11.78 %	13.02 %

[ 3] <sup>233</sup>U

Time	1.0S	1.0HR	1.0D	50.0D	100.0D	1000.0D	5000.0D	1.0E+04D
K <sub>eff</sub>	1.0527	1.0527	1.0523	1.0531	1.0562	1.0414	1.0453	1.0583
CR	0.7804	0.7804	0.7807	0.7697	0.7594	0.7056	0.6045	0.5692
w/o U233	10.75 %	10.75 %	10.75 %	10.63 %	10.52 %	9.48 %	9.44 %	9.59 %



[ 4 ]

Isotope	Notation	Mass	100 Day State				
			Mole	M.F	A.AB.R	W.P.	N.D.
U233	92233	233	1.0292E+03	1.2436E-03	43.0405%	1.0863E-02	3.0700E-04
Th232	90232	232	3.4987E+04	4.2276E-02	72.5899%	3.6771E-01	1.0436E-02
U238	92238	238	8.5042E+03	1.0276E-02	84.3258%	9.1691E-02	2.5367E-03
Be9	4009	9	5.1344E+04	6.2042E-02	88.6314%	2.0934E-02	1.5316E-02
Pu239	94239	239	2.4201E+01	2.9243E-05	91.4360%	2.6203E-04	7.2189E-06
F19	9019	19	5.0700E+05	6.1263E-01	94.1410%	4.3639E-01	1.5123E-01
U235	92235	235	5.7277E+01	6.9210E-05	96.2556%	6.0976E-04	1.7085E-05
Lil7	3007	7	2.2457E+05	2.7136E-01	98.0825%	7.1214E-02	6.6988E-02
Li6	3006	6	2.3317E+01	2.8174E-05	99.1964%	6.3377E-06	6.9552E-06
Sm149	62649	149	1.0356E-01	1.2513E-07	99.4182%	6.9901E-07	3.0890E-08
Pu240	94240	240	1.2725E+00	1.5376E-06	99.5657%	1.3835E-05	3.7958E-07
U234	92234	234	1.2295E+01	1.4856E-05	99.6988%	1.3033E-04	3.6675E-06
Ho165	67665	165	2.2915E+00	2.7689E-06	99.7501%	1.7129E-05	6.8354E-07
Pa233	91233	233	2.0730E+00	2.5048E-06	99.7900%	2.1881E-05	6.1835E-07
Pm147	61647	147	5.9136E-01	7.1456E-07	99.8244%	3.9381E-06	1.7640E-07
Sm151	62651	151	1.2444E-01	1.5036E-07	99.8578%	8.5122E-07	3.7119E-08
Nd143	60643	143	1.7748E+00	2.1446E-06	99.8797%	1.1498E-05	5.2942E-07
Pu241	94241	241	1.5813E-01	1.9108E-07	99.8960%	1.7265E-06	4.7170E-08
Nd145	60645	145	1.6103E+00	1.9458E-06	99.9090%	1.0578E-05	4.8035E-07
Sm152	62652	152	1.3013E-01	1.5724E-07	99.9206%	8.9607E-07	3.8817E-08
Np239	93239	239	9.8745E-01	1.1932E-06	99.9306%	1.0691E-05	2.9455E-07
Pr143	59643	143	8.4196E-01	1.0174E-06	99.9376%	5.4543E-06	2.5115E-07
Nd147	60647	147	2.4721E-01	2.9871E-07	99.9446%	1.6463E-06	7.3741E-08

mole : Total Mole Number

M.F : Mole Fraction

A.AB.R : Accumulate Absorption Rate

W.P : Weight Percent

N.D. : Number Density

[ 5 ]

Absorption XS				XS unit : barn		
Isotope	Helios 77 Group	Helios 3 Group	ORIGEN2	Error (H77-H3)	Error (H77-O)	Error (H3-O)
U233-Xab	7.9683E+01	8.7293E+01	5.4741E+01	8.7176%	45.5631%	59.4647%
TH232-Xab	1.4651E+00	1.4899E+00	1.3838E+00	1.6669%	5.8715%	7.6662%
U238-Xab	1.9459E+00	1.8489E+00	1.7760E+00	5.2499%	9.5693%	4.1040%
BE9-Xab	-5.5533E-02	-2.0341E-02	1.1081E-01	-173.0070%	150.1169%	118.3574%
PU239-Xab	3.6285E+02	3.9026E+02	1.4981E+02	7.0256%	142.2024%	160.5045%
F19-Xab	1.4449E-02	7.1828E-03	7.0496E-03	101.1574%	104.9591%	1.8899%
U235-Xab	7.6212E+01	8.3890E+01	3.9733E+01	9.1529%	91.8105%	111.1355%
LI7-Xab	5.2118E-03	5.8295E-03	1.0746E-02	10.5966%	51.5001%	45.7516%
LI6-Xab	1.0893E+02	1.2111E+02	6.3143E+01	10.0519%	72.5155%	91.7944%
SM149-Xab	9.3540E+03	1.0559E+04	5.5090E+03	11.4129%	69.7949%	91.6700%
PU240-Xab	1.8013E+02	1.9885E+02	1.7971E+02	9.4156%	0.2291%	10.6472%
U234-Xab	2.1500E+01	2.2772E+01	1.3881E+01	5.5837%	54.8862%	64.0461%
HO165-Xab	1.9716E+01	2.0363E+01	2.8301E+01	3.1789%	30.3353%	28.0480%
PA233-Xab	1.7805E+01	1.8802E+01	1.4351E+01	5.3038%	24.0638%	31.0124%
PM147-Xab	4.7445E+01	5.0607E+01	5.1588E+01	6.2484%	8.0309%	1.9014%
SM151-Xab	8.7926E+02	1.0051E+03	3.5401E+02	12.5206%	148.3676%	183.9154%

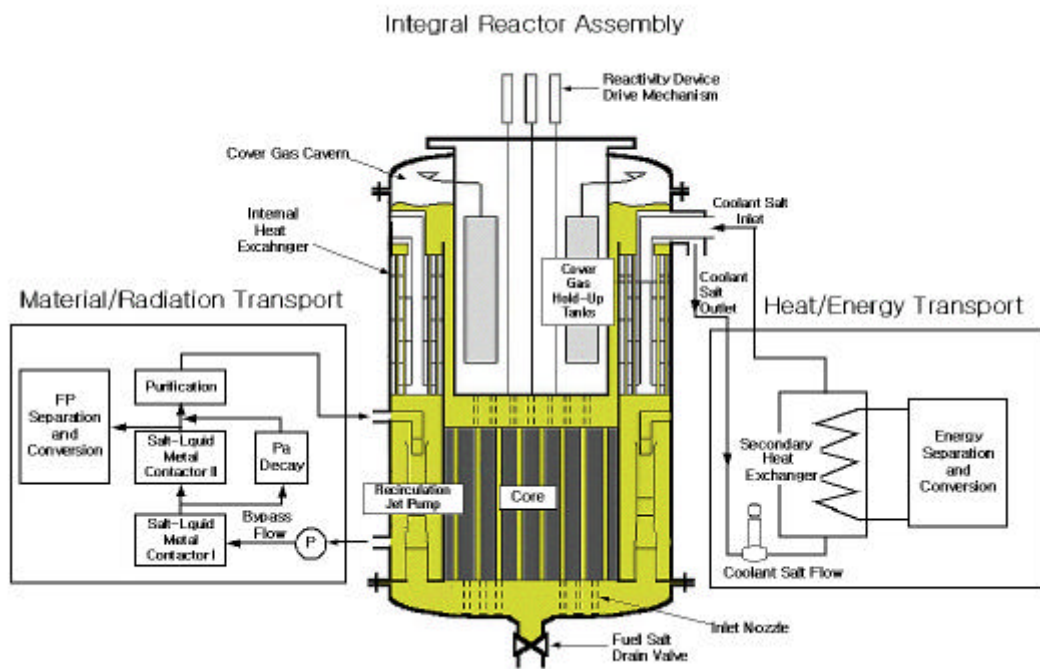
Absorption XS						XS unit : barn
Isotope	Helios 77 Group	Helios 3 Group	ORIGEN2	Error (H77-H3)	Error (H77-O)	Error (H3-O)
ND143-Xab	3.6182E+01	4.0099E+01	1.6301E+01	9.7689%	121.9674%	145.9988%
PU241-Xab	2.7511E+02	3.0070E+02	1.3072E+02	8.5121%	110.4578%	130.0389%
ND145-Xab	8.4983E+00	8.9301E+00	1.0602E+01	4.8352%	19.8399%	15.7671%
SM152-Xab	6.3182E+01	6.8380E+01	1.1801E+02	7.6013%	46.4611%	42.0567%
NP239-Xab	1.7723E+01	1.8105E+01	1.3377E+01	2.1122%	32.4896%	35.3484%
PR143-Xab	1.3084E+01	1.3929E+01	1.1100E+01	6.0624%	17.8748%	25.4820%
ND147-Xab	5.5193E+01	6.0254E+01	3.7000E+01	8.3988%	49.1714%	62.8488%

[ 6 ]

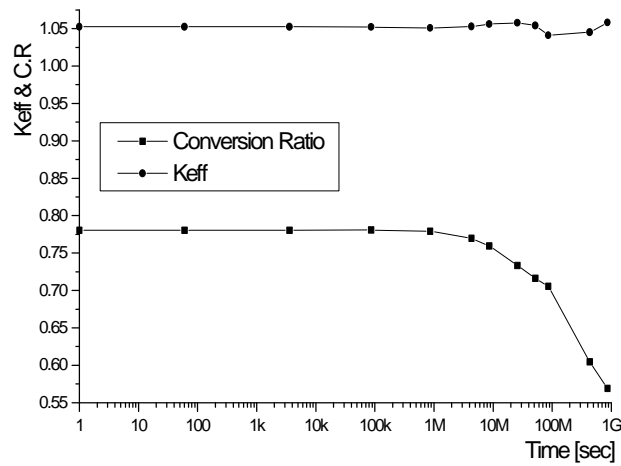
Fission XS						XS unit : barn
Isotope	Helios 77 Group	Helios 3 Group	ORIGEN2	Error (H77-H3)	Error (H77-O)	Error (H3-O)
U233-Xfi	7.1657E+01	7.8490E+01	4.5300E+01	8.7063%	58.1823%	73.2675%
TH232-Xfi	5.0347E-02	2.5507E-02	3.2670E-02	97.3853%	54.1074%	21.9256%
U238-Xfi	2.0129E-01	1.0571E-01	1.0310E-01	90.4152%	95.2405%	2.5341%
BE9-Xfi	0.0000E+00	0.0000E+00	0.0000E+00	0.0000%	0.0000%	0.0000%
PU239-Xfi	2.2676E+02	2.4436E+02	9.0520E+01	7.2064%	150.5027%	169.9567%
F19-Xfi	0.0000E+00	0.0000E+00	5.0900E-04	0.0000%	100.0000%	100.0000%
U235-Xfi	6.3468E+01	7.0041E+01	3.0470E+01	9.3851%	108.2957%	129.8691%
LI7-Xfi	0.0000E+00	0.0000E+00	1.3400E-03	0.0000%	100.0000%	100.0000%
LI6-Xfi	0.0000E+00	0.0000E+00	0.0000E+00	0.0000%	0.0000%	0.0000%
SM149-Xfi	0.0000E+00	0.0000E+00	5.7900E-04	0.0000%	100.0000%	100.0000%
PU240-Xfi	9.8519E-01	6.6122E-01	6.1390E-01	48.9942%	60.4799%	7.7088%
U234-Xfi	8.9358E-01	6.0381E-01	4.9100E-01	47.9913%	81.9921%	22.9748%
HO165-Xfi	0.0000E+00	0.0000E+00	1.4410E+00	0.0000%	100.0000%	100.0000%
PA233-Xfi	3.0815E-01	1.6261E-01	1.9960E-01	89.5092%	54.3848%	18.5344%
PM147-Xfi	0.0000E+00	0.0000E+00	4.4360E-04	0.0000%	100.0000%	100.0000%
SM151-Xfi	0.0000E+00	0.0000E+00	3.2170E-04	0.0000%	100.0000%	100.0000%
ND143-Xfi	0.0000E+00	0.0000E+00	3.6530E-04	0.0000%	100.0000%	100.0000%
PU241-Xfi	2.0367E+02	2.2270E+02	9.8170E+01	8.5461%	107.4626%	126.8494%
ND145-Xfi	0.0000E+00	0.0000E+00	6.2970E-04	0.0000%	100.0000%	100.0000%
SM152-Xfi	0.0000E+00	0.0000E+00	7.8050E-04	0.0000%	100.0000%	100.0000%
NP239-Xfi	1.0066E+00	6.7940E-01	2.1930E+00	48.1598%	54.0994%	69.0195%
PR143-Xfi	0.0000E+00	0.0000E+00	0.0000E+00	0.0000%	0.0000%	0.0000%
ND147-Xfi	0.0000E+00	0.0000E+00	0.0000E+00	0.0000%	0.0000%	0.0000%

[ 7 ]

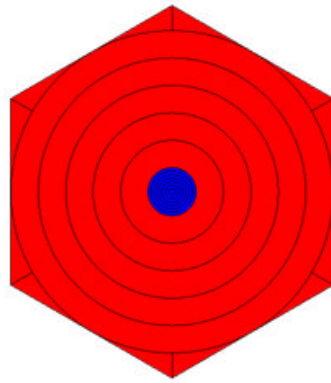
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Li	1.5723E+03	1.5721E+03	0.014%
Be	4.6206E+02	4.6200E+02	0.013%
Th	8.1887E+03	8.1876E+03	0.014%
U235	1.4691E+01	1.5738E+01	-7.129%
U233	2.4576E+02	1.0300E+02	58.090%
U238	2.0257E+03	2.1701E+03	-7.129%
F	9.6326E+03	9.6313E+03	0.014%
Total	2.2142E+04	2.2142E+04	0.000%



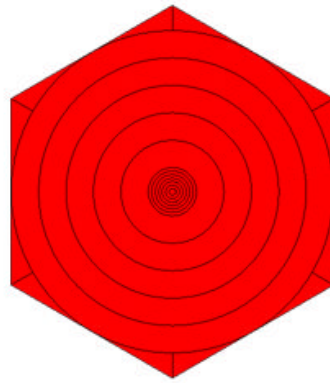
[ 1 ] AMBIDEXTER



[ 2 ] AMBIDEXTER

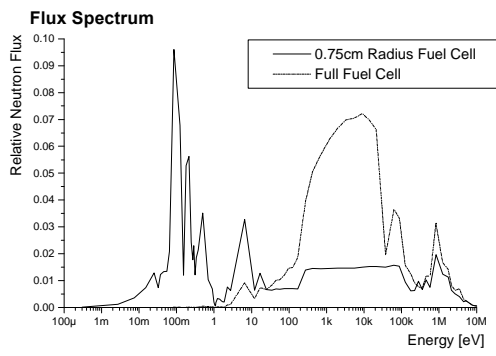


0.75cm Fuel Radius Lattice

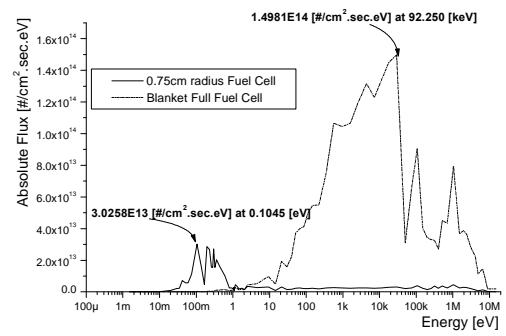


Blanket Full Lattice

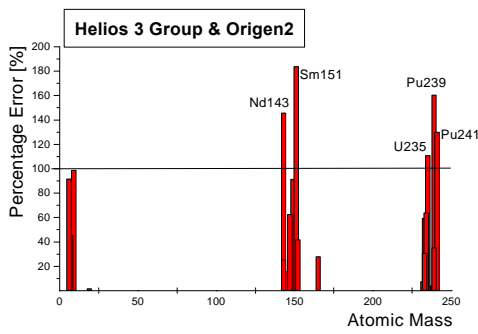
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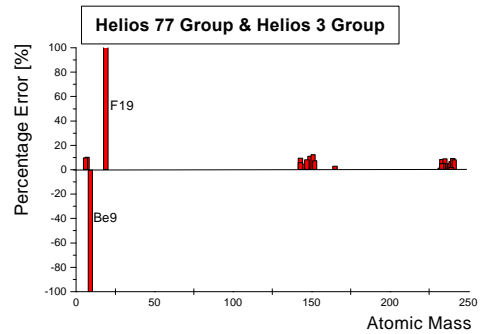


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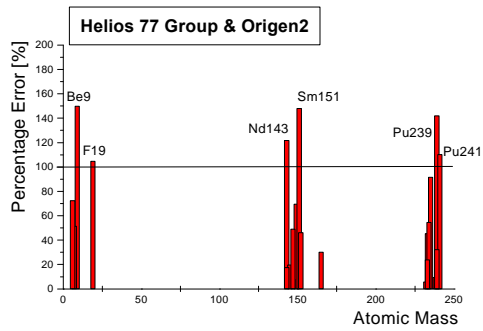
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ORIGEN2

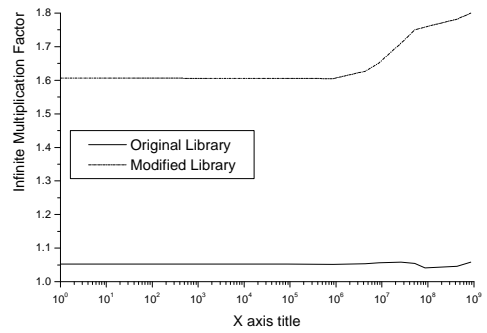


[ 7 ] 77

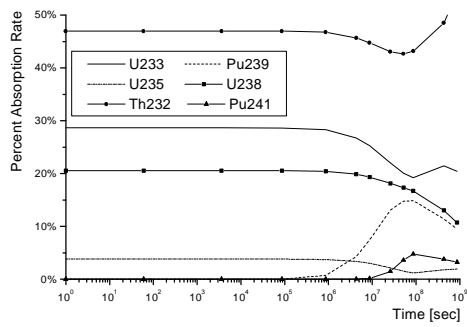
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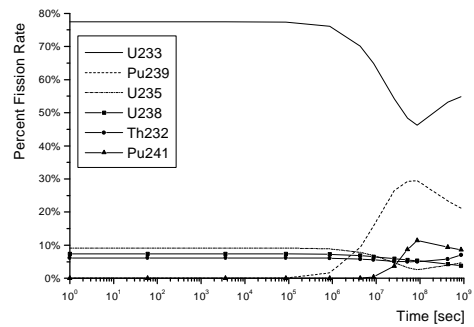
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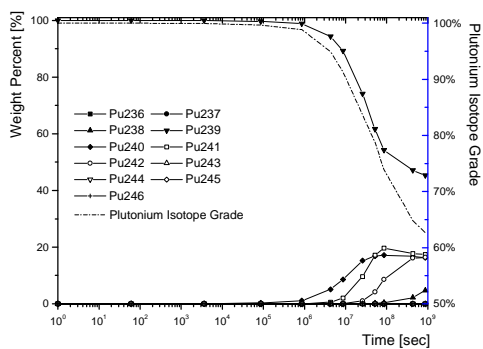
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AMBIDEXTER



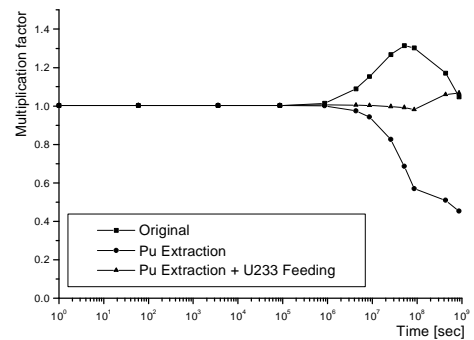
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[ 12 ] Pu



[ 13 ] Pu