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ASSESSMENT STUDIES FOR ACTINIDES WASTE

by E. Schmidt

Envisaging high burn-up rates and fuel recycling in nuclear fission reactors leads to a significant generation of actinides other than fuel with implications for such different fields as radioactive waste disposal, fuel element fabrication and in-core neutron physics.

Actinides and their daughters represent a special problem in the radioactive waste disposal because of the high radio-toxicity of α -particle emitters and the long half-lives of many of these isotopes. This fact of matter is illustrated in Fig. 1a. While the relative radiotoxic risk coming from fission products decreases to acceptable levels within decay periods of less than 1000 years, actinides would represent a hazard risk until 100.000 years and longer unless they will be extracted from the fission product waste.

A probable future high-level radioactive waste disposal policy could be to store waste in geological formations. However, since it is impossible to predict with sufficient reliability the tectonics of geological formations for such long periods as needed that actinides decay to innocuous radiation levels, the transmutation of actinides in power reactors themselves will be studied as one of their possible ultimate disposal techniques. The questions to be answered in this frame refer to:

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- the neutron-physical feasibility of burning actinides
- the required extraction degrees of individual actinides from radioactive waste, in order to justify this procedure
- the technical implications for reactor operation and fuel cycle caused by recycling actinides.

Recently, a study on the magnitude of the actinides problem has been completed at Ispra, giving a forecast of the actinides waste to be generated by the nuclear power industry of the member countries of the European Communities until the year 2000, a first result for the accumulation of actinides in the case of their homogeneous recycling through a lightwater reactor, and the effect of actinides separation from waste on the relative radiotoxic risk of the waste, respectively. The corresponding burn-up calculations were performed by means of the computer program ORIGEN /1/. The nuclear cross section libraries for the natural uranium-fed graphite-moderated reactor (GGR), advanced graphite-moderated reactor (AGR) and the steam-generating heavy water-moderated reactor (HWR) have been generated approximating mass flows for the individual isotopes calculated at Berkeley (England) by the program HYLAS-2 /2/.

The characteristics of all nuclear reactor types used or scheduled for energy generation in the EC are reproduced in Table 1. The specific generation of α -waste in grams per GWD_e of energy produced is shown in Table 2, assuming that 0.5% of fuel and all other actinides go to the waste. It may be seen that the reactors behave differently from a point of view of α -waste production. Looking at the column where the total α -waste without fuel is tabled, three classes of reactors can be defined. GGR, AGR and HWR have the lowest generation rate of higher actinides. In a

second class, the uranium-fed LWR, the THTR and the MFBR can be gathered. The "worst" reactor is presented by the light water reactor with plutonium recycling. It produces more than 10 times as much α -waste as the reactors of the first class do.

An other interesting result is the relatively high plutonium production in a thorium-fueled reactor. In order to reduce the hazard represented by the radioactive waste, the possibility of a recovery of plutonium in the thorium-uranium fuel cycle should be taken in consideration.

Employing a forecast for the nuclear energy generation in the EC established by the Commission of the EC after the oil crisis of 1973/74 in collaboration with delegates of the member states, the yearly production rates of α -wastes and the cumulative production until the year 2000 have been evaluated and summarized in Table 3 . It may be noticed that the cumulative generation of α -wastes other than fuel will be in the case of plutonium recycling through LWR's about 4 times larger than in the case where no plutonium recycling through thermal reactors would be applied. The results of a homogeneous recycling of higher actinides through a LWR are given in Table 4 . After about 20 cycles an equilibrium concentration for the higher actinides is obtained, demonstrating so the neutron-physical feasibility of burning actinides in fission reactors. The quantity of actinides within the reactor in the case of recycle would only be three times greater than in the case without recycling.

A first indication regarding the effect of extracting higher actinides on the relative radiotoxic risk of the radioactive waste is shown in Table 5 . There, the relative radiotoxic risk of α -waste without actinides separation is compared with that where 99.5% of actinides have been extracted. The aim of a more detailed

study will be to determine the needed extraction degrees for individual nuclides in order to get after a decay time of 1000 year acceptable figures for the relative radiotoxic risk for all reactor types.

References

- /1/ M.J. Bell, ORIGEN, the ORNL Isotope Generation and Depletion Code; ORNL-4628, May 1973.
- /2/ S.M. Beynon, FISP 4 and HYLAS 2: Updated versions of the Computer Programs for calculating Radioactive Fuel Inventories; RD/B/N 2633, April 1973.

FIG. 1a:
 U-FEEDED LWR
 BU = 27000 MWD/T

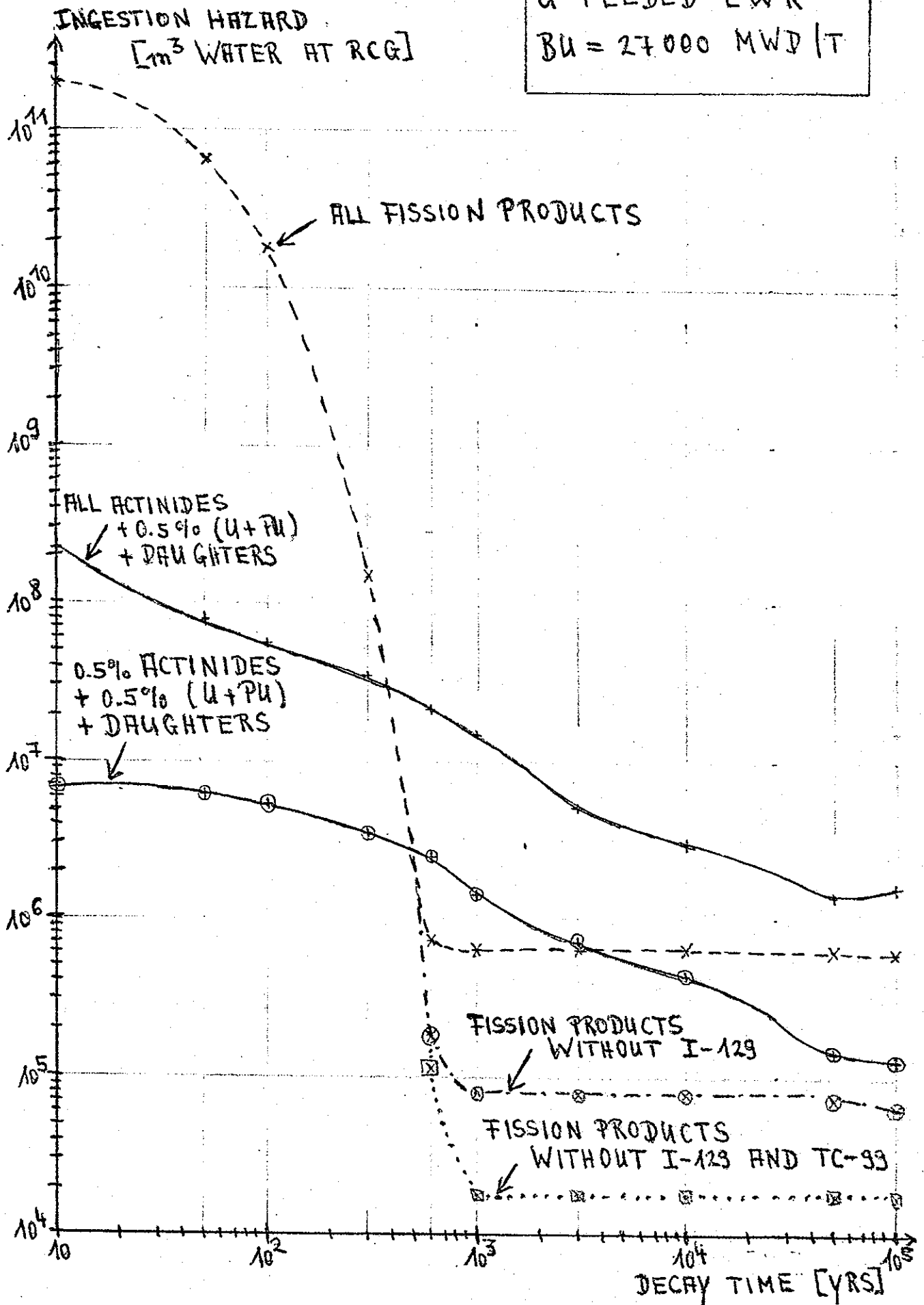


TABLE 1 : CHARACTERISTIC DATA FOR NUCLEAR REACTORS

REACTOR TYPE		U-LWR	PU-LWR	GGR	AGR	HWR	THTR	MFBR	
THERMAL EFFICIENCY [%]		33	33	30	42	33	39	34	
THERMAL POWER RATING [MW _{th} /T]		38	38	3.7	12.5	19.8	73	143.9	
MEAN BURN-UP [MWD/T]		33 000	33 000	4 000	18 000	20 700	93 500	79 000	
NATURAL U / TH NEEDED FOR PRODUCING 1 TON OF FUEL [TONS]	U	6.8		1	4.5	4.3	10.1		
	TH						0.95		
STEADY - STATE CHARGING VECTOR [%]		TH-232					90.79		
		U-235					2.32		
		U-238	3.19	0.69	0.71	2.23	2.11	4.61	0.22
		U-238+36	96.78	94.49	99.28	97.75	97.87	1.26	81.61
		PU-239		2.22					11.43
		PU-241		0.82					0.91
		PU-240+42		1.77					5.83
		U-234	0.03	0.01	0.01	0.02	0.02	1.02	

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TABLE 2 : SPECIFIC GENERATION OF α -WASTE [GRAMS PER GWDe], ASSUMING
 THAT 0.5% OF FUEL AND 100% OF OTHER ACTINIDES GO TO WASTE.

REACTOR TYPE		U-LWR	PU-LWR	GGR	AGR	HWR	THTR	MFBR (CORE)
WEIGHT OF INDIVIDUAL ELEMENTS IN [GRAMS PER GWDe GENERATED]	TH	9.7 (-5)	2.9 (-5)	4.3 (-4)	3.2 (-4)	2.5 (-4)	1.2 (+2)	8.0 (-7)
	PA	3.8 (-5)	9.8 (-6)	2.6 (-5)	4.8 (-5)	4.5 (-5)	4.8 (-1)	4.8 (-7)
	U	4.4 (+2)	4.2 (+2)	4.1 (3)	6.6 (+2)	7.0 (+2)	7.9 (+0)	1.4 (+2)
	NP	4.4 (+1)	1.1 (+1)	2.3 (+1)	2.3 (+1)	2.4 (+1)	6.1 (+0)	1.2 (+1)
	PU	4.1 (+0)	1.5 (+1)	1.0 (+1)	3.4 (+0)	4.3 (+0)	4.6 (+1)	3.3 (+1)
	AM	1.3 (+1)	2.8 (+2)	5.4 (+0)	6.6 (+0)	6.2 (+0)	1.2 (+0)	3.8 (+1)
	CM	3.7 (+0)	1.8 (+2)	1.1 (-1)	3.0 (-1)	5.8 (-1)	5.8 (-1)	1.6 (+1)
	BK	1.8 (-7)	2.8 (-5)	1.5 (-14)	6.4 (-11)	5.0 (-10)	1.4 (-7)	2.6 (-9)
	CF	1.7 (-7)	2.5 (-5)	1.2 (-14)	6.1 (-11)	4.5 (-10)	3.6 (-7)	1.7 (-9)
TOTAL		5.0 (2)	9.1 (2)	4.1 (3)	6.9 (2)	7.4 (2)	1.8 (2)	2.4 (2)
TOTAL WITHOUT FUEL		6.1 (1)	4.7 (2)	2.9 (1)	3.0 (1)	3.1 (1)	5.4 (1)	6.6 (1)

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TABLE 3 : PROJECTIONS OF α -WASTES TO BE GENERATED BY THE NUCLEAR POWER INDUSTRY IN KILOGRAMS.

ELEMENT \ YEAR	1975		1980		1990		2000		1975 - 2000			
	ONLY	U-LWR	PU-RECYC.	ONLY	U-LWR	PU-RECYC.	ONLY	U-LWR	PU-RECYC.	ONLY	U-LWR	PU-RECYC.
TH [KG]	-		9.7 (1)		5.6 (2)		6.2 (3)		3.6 (4)		3.6 (4)	
PH "	-				2.3 (0)		2.5 (1)		1.5 (2)		1.5 (2)	
U "	8.2 (3)		1.3 (4)		5.8 (4)		1.0 (5)		1.2 (6)		1.2 (6)	
NP "	1.3 (2)		5.9 (2)		4.6 (3)		8.7 (3)		9.5 (4)		7.4 (4)	
PU "	3.0 (1)		8.1 (1)		8.3 (2)		4.2 (3)		3.1 (4)		3.7 (4)	
AM "	3.9 (1)		1.8 (2)		1.5 (3)		3.6 (3)		3.5 (4)		2.1 (5)	
CM "	8.7 (0)		4.7 (1)		4.4 (2)		1.2 (3)		1.1 (4)		1.2 (5)	
TOTAL "	8.4 (3)		1.4 (4)		6.6 (4)		1.3 (5)		1.4 (6)		1.7 (6)	
TOTAL WITHOUT FUEL "	1.7 (2)		9.1 (2)		6.7 (3)		1.6 (4)		1.6 (5)		5.7 (5)	
RADIOACTIVITY [Mci]	4.3 (0)		2.3 (1)		1.9 (2)		4.5 (2)		4.5 (3)		2.4 (4)	

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TABLE 4 : CHANGE OF ACTINIDES' CONCENTRATIONS
OTHER THAN FUEL BY RECYCLING THEM THROUGH
A LWR.

ELEMENT	FIRST CYCLE		TWENTIETH CYCLE	
	MASS [GRAMS]	RRR	MASS [GRAMS]	RRR
TH	2.3 (-4)	1.1 (-3)	2.1 (-3)	1.2 (-3)
PA	4.3 (-5)	1.7 (-4)	1.3 (-4)	4.7 (-4)
NP	358	1.4 (-2)	987	2.7 (-3)
AM	111	2.7	137	2.9
CM	24.4	53.6	277	165
BK	5.8 (-7)	1.6 (-7)	0.30	8.5 (-2)
CF	5.6 (-7)	1.6 (-7)	0.94	0.92
TOTAL	493.4	62.3	1402	168.0

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TABLE 5: RRR [m³ WATER AT RCG] OF α -WASTE DIVIDED BY RRR OF TAILINGS FROM PRODUCING ONE TON OF NATURAL URANIUM.*

DECAY TIME [YRS]	EXTR.	U-LWR	PU-LWR	GGR	AGR	HWR	THTR	MFBR
100	0	4.0	74.0	0.35	2.1	1.7	121	40.4
	0.995	0.42	2.6	0.042	0.17	0.19	0.64	3.5
400	0	2.0	291.	0.22	1.2	0.97	15.4	28.3
	0.995	0.23	1.3	0.031	0.11	0.12	0.096	2.8
600	0	1.5	24	0.16	0.90	0.71	5.8	17.3
	0.995	0.18	0.99	0.026	0.089	0.097	0.054	2.2
1 000	0	1.0	19	0.032	0.51	0.41	2.4	10.5
	0.995	0.12	0.62	0.020	0.061	0.067	0.050	1.7
3 000	0	0.43	12	0.017	0.093	0.099	1.2	2.4
	0.995	0.049	0.22	0.013	0.029	0.032	0.11	1.1
10 000	0	0.27	7.2	0.010	0.052	0.060	2.1	1.3
	0.995	0.031	0.13	0.009	0.019	0.021	0.28	0.64
100 000	0	0.12	1.1	0.008	0.042	0.048	11.1	0.34
	0.995	0.016	0.062	0.003	0.012	0.011	0.77	0.035

* AS FUNCTION OF DECAY TIME AND EXTRACTING 0% AND 99.5% OF ACTINIDES.

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