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Analysis of LWR Full MOX Core Physics Experiments with Major Nuclear Data Libraries

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1. Introduction

Nuclear Power Engineering Corporation (NUPEC) studied high moderation full MOX cores[1] as a part of advanced LWR core concept studies from 1994 to 2003 supported by the Ministry of Economy, Trade and Industry. In order to obtain the major physics characteristics of such advanced MOX cores, NUPEC carried out core physics experimental programs called MISTRAL[2] and BASALA[3] from 1996 to 2002 in the EOLE critical facility of the Cadarache Center in collaboration with CEA. NUPEC also obtained a part of experimental data of the EPICURE program[4] that CEA had conducted for 30 % Pu recycling in French PWRs. Japan Nuclear Energy Safety Organization(JNES) established in 2003 as an incorporated administrative agency took over the NUPEC's projects for nuclear regulation and has been implementing FUBILA program[5] that is for high burn up BWR full MOX cores.

This paper presents an outline of the programs and a summary of the analysis results of the criticality of those experimental cores with major nuclear data libraries.

2. Outline of Core Physics Experimental Programs

2.1 Critical Facility

The EOLE facility consists of: (1) a core cylindrical vessel (diameter = 1 m and height = 1 m) containing the core composing moderator (light water), fuel rods and related structures; (2) control rods (four safety clusters and one pilot rod) linked to the over-structure; (3) water circuits used to fill up and empty the core vessel with the moderator, introduce soluble boron and control the moderator temperature at any temperature between 5°C and 85°C.

2.2 Core Configuration

The major core parameters are shown in Table 1 to 3 for the four programs. The MOX fuel rods of total Pu 4.3, 7.0 and 8.7 % used for MISTRAL and BASALA were fabricated for EPICURE before 1990 (EPICURE MOX rods) and the specifications are same as PWR 17x17 type fuel except for the fuel effective length of 80 cm. The MOX fuel rods of total Pu 3.0, 5.0, 8.5 and 11.5% used in FUBILA (FUBILA MOX rods) were newly fabricated in 2004 and are mock up of BWR 9x9 type fuel. The Pu of those MOX fuel contains fissile Pu of 60 to 70 % and more than 20 % of 240Pu. FUBILA MOX rods have lower 241Am and EPICURE MOX MOX rods higher 241Am.

Table 1 Core parameters of EPICURE program

Program	EPICURE			
Core	UH1.2	MH1.2	UM17x17 /7%	UM17x17 /11%
Core Config-ration	UO2 Homo-geneous	Partial MOX Homo-geneous	Partial MOX 17x17 Mockup	Partial MOX 17x17 Mockup
-Vm/Vf	1.3	1.3	1.3	1.3
-H/HM	3.7	3.7	3.7	3.7
-Fuel pitch cm	1.26	1.26	1.26	1.26
-Fuel rod type	UO2-3.7%	MOX-7.0% UO2-3.7%	MOX-7.0% UO2-3.7%	MOX-11% UO2-3.7%
-Core size	D=54cm	D=69cm	D=58cm	D=55cm

Table 2 Core parameters of MISTRAL program

Program	MISTRAL				
Core	Core 1	Core 2	Core 3	Core4 Full MOX	Core4 UO2 zone
Core Config-ration	UO2 Homo-geneous	Full MOX Homo-geneous	Full MOX Homo-geneous	Full MOX 17x17 Mock-up	UO2 17x17 Mock-up in MOX
-Vm/Vf	1.8	1.8	2.1	2.0	2.0
-H/HM	5.1	5.1	6.2	5.8	5.8
-Fuel pitch cm	1.32	1.32	1.39	1.32	1.32
-Fuel rod type	UO2-3.7%	MOX-7.0, 8.7%	MOX-7.0%	MOX-7.0%	MOX-7.0% UO2-3.7%
-Core size	D=41 cm	D=60 cm	D=59 cm	D=62 cm	D=52 cm

Table 3 Core parameters of BASALA and FUBILA programs

Program	BASALA		FUBILA	
Core	Core 1	Core 2	9x9 Ref	10x10
Core Config-ration	Full MOX BWR Mockup	Full MOX BWR Mockup	Full MOX BWR Mockup	Full MOX BWR Mockup
-Vm/Vf	1.7	3.1	1.7	1.7
-H/HM	5.0	9.0	5.0	5.0
-Fuel pitch cm	1.13 (in Assembly)	1.35 (in Assembly)	14.9 (in Assembly)	13.4 (in Assembly
-Fuel rod type	MOX-3.0, 4.3,7.0,8.7 %(Test region) MOX-7.0% (Driver region)	MOX-3.0, 4.3,7.0,8.7 %(Test region) MOX-7.0% (Driver region)	MOX-3.0, 5.0,8.5,11.5 %(Test region) MOX-7.0% (Driver region)	MOX-3.0, 5.0,8.5,11.5%(Test region) MOX-7.0% (Driver region)
-Core size	XY=61cm	XY=47cm	XY=54cm	XY=57cm

3. Analysis Method

Three dimensional continues energy Monte Carlo calculations were performed using MVP code [6] with detail treatment of geometry and neutron energy using MVP's library processed from JENDL-3.2 and 3.3, ENDF/B-VI, JEF-2.2 and JEFF-3.1. A number of simulated particles was 10,000 per batch x 1,000 to 2000 batches.

4. Analysis Results

The calculated critical keff of the six full MOX cores in these programs are shown in Figure 1 comparing with the two UO2 cores, the four mixed cores as a parameter of the nuclear data libraries.

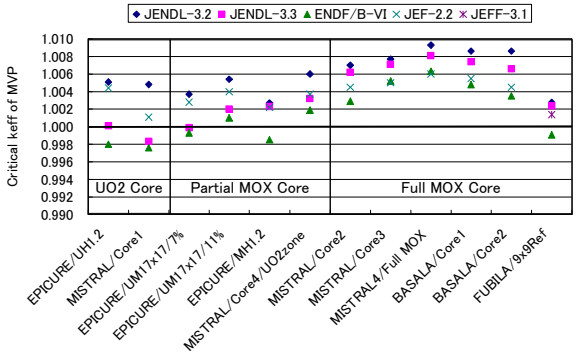

Figure 1 Critical keff of MVP

One of observations of those results is that all libraries including the latest library, ENDF/B-IV and JENDL-3.3 show over estimate of keff for the full MOX cores of MISTRAL and BASALA where the old MOX fuel is used. On the other hand, the keff of FUBILA where newly fabricated MOX fuel was used in the core center surrounded by driver region of the old 7.0 % MOX is close to 1.0. The other is that the level of the overestimate is increasing with the elapse time of the used MOX fuel in MISTRAL. Those facts indicates that the change of Pu composition caused by the decay of 241Pu and the pile up of 241Am influences the keff. Therefore it is need to improve the cross sections of those nuclides in thermal and resonance energy regions.

Table 4 Cases of increase(%) of 241Am cross section

Case	Thermal group <1.855eV	Epi-thermal group 1.855eV-5.53keV
A	+10	+20
B	+25	+30

As one of options for improving the cross sections, a study of increasing a capture cross section of 241Am has been conducted [8] with a deterministic code system SRAC[7] with JENDL-3.2. Figure 2 shows the change of keff of MISTRAL full MOX cores and EPICURE partial MOX core, MH1.2, with increase of thermal and epithermal group cross sections as shown in Table 4. This study shows a high sensitivity of 241Am capture cross section to keff of MISTRAL full MOX cores.

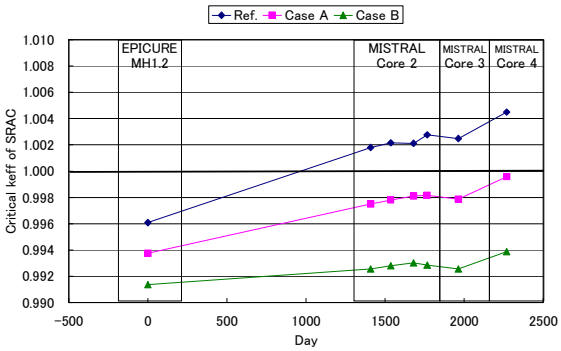

Figure 2 Critical keff of with increase of 241Am capture cross section[8]

5. Conclusion

The critical analysis has been performed for the full MOX cores of MISTRAL, BASALA and FUBILA, and keff has been compared with each other and also with the UO2 and the partial MOX cores with the major nuclear data libraries. An systematic trend of keff caused by the change of the Pu composition were observed. The sensitivity study showed that the 241Am capture cross section is highly related to this trend.

REFERENCES

[1] T. Kanagawa et al., "Study of Advanced LWR Cores for Effective Use of Plutonium," Proc. Int. Conf. on Future Nuclear Systems, Global'97, Yokohama, Japan, Oct. 5-10, 1997, Vol. 1, p.281 (1997).
[2] K. Hibi et al., "Analyses of MISTRAL and EPICURE Experiments with SRAC and MVP Code Systems," Proc. Int. Topical Meeting on Advances in Reactor Physics and Math. and Comp. into the Next Millenium, Physor2000, Pittsburg, USA, May 7-12, 2000, p.IX.E-5 (2000).
[3] T. Yamamoto et al., " Core Physics Experiments and Their Analyses of High Moderation Full MOX BWR," Proc. of GENES4/ANP2003, Sep. 15-19, 2003, Kyoto, Japan.
[4] J.P Chauvin et al., "EPICURE: an Experimental Programme Devoted to the Validation of the Calculational Schemes for Plutonium Recycling in PWR," Int. Conf. on Physics of Reactors: Operation, Design and Computation, PHYSOR 1990, Marseille, France, April 23-27, 1990.
[5] T. Yamamoto et al., " FUBILA: core physics experimental program aimed at validation of core analysis method for high burn up BWR full MOX cores," Proc. Int. Conf. GLOBAL 2005, Tsukuba, Japan, Oct 9-13, 2005, Paper 092 (2005).
[6] Y. Nagaya et al., "MVP/GMVP II: general purpose Monte Carlo codes fro neutron and photon transport calculations based on continuous energy and multigroup methods," JAERI-1348 (2005).
[7] K. Okumura, K. Kaneko and K. Tsuchihashi, JAERI-Data/Code 96-018 (1996) [in Japanese].
[8] Research report "Study of LWR Cores for Effective Use of Pu," NUPEC, March 2002 (2002) [in Japanese].