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STATUS OF REDUCED ENRICHMENT PROGRAM FOR RESEARCH REACTORS IN JAPAN

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ABSTRACT

The current status of research and test reactors relevant to RERTR program is described. The reduced enrichment programs for the JRR-3, JRR-4 and JMTR of Japan Atomic Energy Agency (JAEA) were completed by 1999. The core of JRR-3 was converted from aluminide (UAl_X-Al) to silicide (U_3Si_2-Al) in order to reduce the amount of spent fuel. The JRR-3 has been well operated with LEU fuel since 1990 and reached 55,400 MWD in December 2007 at the last operation cycle. Operation with 10 cycles (26 days/cycle) is scheduled for one year from July 2008 to July 2009.

The JRR-4 is under shut down condition to replace reflector elements with new ones. It will restart in July 2009.

The JMTR is under refurbishment of irradiation facilities.

The JAEA established a committee in July 2008 to study the following terms:

1. Supply of nuclear fuel
2. Transportation of spent fuels and fuel disposition
3. Development situation of the U-Mo fuel

Kyoto University Research Reactor (KUR) has terminated its operation with HEU on February 2006. Shipment of all HEU spent fuel elements to the United States has been successfully completed. The full core conversion to LEU fuel, including fuel fabrication, is currently under progress and the reactor restart using LEU core is expected to be achieved in May 2009.

1. Introduction

The objective of the Reduced Enrichment for Research and Test Reactors (RERTR) program is to develop the technology to minimize the use of highly enriched uranium (HEU) in civilian nuclear application worldwide. As the substitute fuels were developed, existing reactors would be converted to use the LEU and new reactors would be designed to use the LEU.

The RERTR program in Japan was pursued under the direction of the "Five Agency Committee" on HEU organized by the Ministry of Education, Ministry of Science and Technology, Ministry of Foreign Affairs, Japan Atomic Energy Research Institute and Kyoto University. The committee started in 1971 until 2000. However, the committee is not opened since 2001 because the LEU conversion activities of the relevant reactors in Japan are considered to be in a closing phase. The history of RERTR program in Japan is shown in Table 1.

In this paper, the following terms are described:

1. Detail of research reactors and critical assemblies in operation in Japan,
2. Current situation of research reactors relevant to the RERTR program in Japan,
3. Spent fuel management in Japan, and
4. Relevant topics in JAEA.

2. Detail of research reactors and critical assemblies in operation in Japan

Eight research reactors and six critical assemblies are operated in Japan. These are shown in Table 2 and Table 3. Four research reactors (the JRR-3, JRR-4 and JMTR of the JAEA and KUR) are concerned within the RERTR program. These research reactors are shown in Table 4.

3. Current situation of research reactors relevant to the RERTR program in Japan

3.1 JAEA

(1) JRR-3

The JRR-3 achieved the first criticality in 1962 as the first research reactor with the homegrown technology and had been utilized in a lot of researches. In 1990, JRR-3 modified for upgrade and resumed its operation as a high performance and multi purpose research reactor with thermal power of 20MW. The JRR-3 is used for production of neutron-transmutation-doped silicon semiconductor, production of radioisotope, neutron scattering experiments, neutron radiography, and activation analysis, etc. The core of JRR-3 was converted from aluminide (UAl_X-Al) to silicide (U_3Si_2-Al) in September 1999 in order to reduce the amount of spent fuel. Uranium density of the silicide fuel is about 4.8Ug/cm^3, and cadmium wires are inserted in each both side plate of fuel element as burnable absorber. The silicide fuel core has 1.6 times as much uranium as that of the aluminide fuel core. Therefore, the amount of spent fuel decreased to about half per year. The JRR-3 has been well operated with LEU fuel since 1990 and reached 55,400 MWD in December 2007 at the last operation cycle.

(2) JMTR and JRR-4

The JMTR was completely converted to LEU fuel in January 1994. The LEU fuel is silicide fuel (U_3Si_2-Al) with 4.8gU/cm^3, and cadmium wire is inserted each one side plate of fuel element. A long-term continuous operation became possible by the convertion of its core to the LEU with high density uranium. The JMTR is under refurbishment of irradiation facilities.

The JRR-4 has 3.5MW of thermal output, and is used for production of neutron-transmutation-doped silicon semiconductor, a clinical trial of BNCT (Boron Neutron Capture Therapy), education and training of reactor engineers, etc. JRR-4 terminated its operation with HEU on January 1996. The full core conversion of JRR-4 to LEU silicide fuel (U_3Si_2-Al) was achieved in July 1998. Uranium density of the silicide fuel is about 3.8Ug/cm^3. After conversion to the LEU fuel, JRR-4 carried out stable operation, and the total thermal output since July 1998 to December 2007 was 763MWD. The JRR-4 is currently under shut down condition to replace reflector elements with new ones. It will restart in July 2009.

(3) Spent Fuel Management in JAEA

Nine shipments for JRR-3, JRR-4 and JMTR spent fuels have been successfully carried out since 1997. The remaining spent fuel elements from JRR-3, JRR-4, JMTR and Japan Materials Test Reactor Critical assembly (JMTRC) are currently being stored in their storage facilities. These elements will be shipped to U.S. under the extended Foreign Research Reactor Spent Nuclear Fuel (FRR SNF) Acceptance Program.

A new contract with DOE will be concluded in autumn 2008. Next transportation of spent fuel elements will be carried out as soon as the problem on insurance of transport path is solved.

3.2 Research Reactor Institute, Kyoto University (KURRI)

The Kyoto University Research Reactor (KUR, 5MW) has been operated since 1964 using HEU fuel. According to the government policy, Kyoto University commenced to convert the KUR to use the LEU fuel, and two LEU silicide fuel elements have been loaded to the core in May, 1992. In 1994, the U. S. Government gave an approval to utilize the HEU fuel material prepared for Kyoto University High Flux Reactor (KUHFR) project, which was officially cancelled in 1991, to be used in the KUR. Therefore, the KUR has been operating with HEU until February 23, 2006.

The HEU spent fuel shipment under the U.S. FRR SNF Acceptance Program has commenced at 1999, and all shipments have been successfully terminated as scheduled. The final (seventh) shipment has been terminated this year, so the HEU spent fuel removal from KUR has successfully terminated.

The extensive use of KUR in BNCT field, as well as both fundamental and applied use in various fields, was a strong motivation for the continuation of the KUR operation with LEU fuel after 2006. It should be noted that the Record of Decision (ROD) concerning the ten-year extension of FRR SNF Acceptance Program issued by the DOE in November 2004 was the key issue for the approval of KUR operation license with LEU after 2006. According to this extension, a new contract concerning the FRR SNF Acceptance Program has been concluded between the DOE and Kyoto University in February 2006, and the safety review for the use of LEU silicide fuel in the core has completed in February 2008. The LEU fuel fabrication is

under progress and the completion of full core conversion of KUR to LEU is expected to be in May 2009.

4. Relevant Topics in JAEA

In July 2008, a new committee was established in JAEA, in order to study about securing fuel method of research reactor and processing method of spent fuel. The committee study mainly about "Supply of nuclear fuel", "Transportation and fuel disposition" and "Development situation of the U-Mo fuel". We will report on the intermediate result of study about subjects of new committee in meeting after the coming year.

5. Summary

The RERTR program in Japan is in a closing phase. The research reactors, which finished conversion of fuel, have been well operated in Japan.

6. Acknowledgements

The operators of the relevant research reactors, JAEA and Kyoto University, would like to acknowledge the continuing support from RERTR program for the successful achievements of LEU conversions of the Japanese research reactors.

Table 1. History of Reduced Enrichment Program for Research and Test Reactors in Japan

1977. 11	Japanese Committee on INFCE WC-8 was started.
1977. 11	Joint Study Program was proposed at the time of the application of export license of HEU for the KUHFR.
1978. 5	ANL-KURRI Joint Study Phase A was started.
1978. 6	Five Agency Committee on Highly Enriched Uranium was organized.
1978. 9	ANL-KURRI Joint Study Phase A was completed.
1979. 5	Project team for RERTR was formed in JAERI.
1979. 7	ANL-KURRI Joint Study Phase B was started.
1980. 1	ANL-JAERI Joint Study Phase A was started.
1980. 8	ANL-JAERI Joint Study Phase A was completed.
1980. 9	ANL-JAERI Joint Study Phase B was started.
1981. 5	MEU UAl_x-AI full core experiment was started in the KUCA.
1983. 3	ANL-KURRI Phase B was completed.

1983. 8	MEU $UA1_x$-Al full core experiment in the JMTRC was started.
1983.11	ANL-KURRI Phase C was started.
1984. 3	ANL-JAERI Phase B was completed.
1984. 4	ANL-JAERI Phase C was started.
1984. 4	MEU-HEU mixed core experiment in the KUCA was started.
1984. 9	Irradiation of 2 MEU and l LEU $UA1_x$-Al full size elements in the JRR-2 was started.
1984. 10	Irradiation of LEU UAl_x-Al full size elements in the JRR-4 was started.
1984. 11	Thermal-hydraulic calculations for the KUR core conversion from HEU to LEU were performed.
1985. 1	Irradiation of MEU UAl_x-Al full size elements in the JMTR was started.
1985. 3	Irradiation of MEU UAl_x-Al full size elements in the JMTR was completed. Irradiation of LEU U_xSi_y-Al mini-plates in the JMTR was started.
1985. 6	Irradiation of LEU U_xSi_y-Al mini-plates in the JMTR was completed.
1985. 10	Neutronics calculations for the KUR core conversion from HEU to LEU were performed.
1986. 1	Irradiation of MEU UAl_x-Al full size elements in the JRR-2 was started.
1986. 5	Irradiation of MEU $UA1_x$-Al full size elements in the JRR-2 was completed.
1986. 8	The JMTR was fully converted from HEU to MEU fuels.
1987.11	MEU UAl_x-Al full core in the JRR-2 was started.
1988. 7	PIE of MEU, LEU UAl_x-Al full size elements in the JRR-2 was completed.
1988. 12	Irradiation of LEU UAl_x-Al full size elements in the JRR-4 was completed.
1990. 3	LEU UAl_x-Al full core test in the new JRR-3 (JRR-3M) was started.
1990. 11	Full power operation of 20MW in the JRR-3M was started.
1992.5	Two LEU U_3Si_2-Al elements were inserted into the KUR core.

1993.11	Two LEU U_3Si_2-Al elements were inserted into the JMTR core.
1994.1	The JMTR was fully converted from MEU to LEU with U_3Si_2-Al fuel.
1994.9	ANL-JAERI Phase C was completed.
1995.12	The JMTRC was shutdown.
1996.12	The JRR-2 was shutdown.
1998.7	The JRR-4 was full converted from HEU to LEU with U_3Si_2-Al fuel.
1999.9	The JRR-3M was fully converted from LEU UAl_x-Al fuel to LEU U_3Si_2-Al fuel.
2000.3	The decommissioning plan for the VHTRC was submitted to the Japanese Government.
2002.1	The decommissioning plan for the DCA was submitted to the Japanese Government.
2002.3	The HTTR operation has been started after the Functional Test completed by the Japanese Government.
2004.4	Core Outlet Gas (He) Temperature of HTTR was reached to 950℃.
2006.2	The KUR operation using HEU was terminated.
2006.8	The JMTR was temporarily shut down to modify the irradiation facilities
2007.12	The JRR-4 was temporarily shut down to replace reflector elements

Table 2. Japanese Research Reactors in Operation

Name	Owner	Site	Type and enrichment			Max. Power	Start-up date
UTR KINKI	Kinki University	Higashi -osaka	H_2O(UTR)	U-Al	90%	1W	1961. 11
JRR-3	JAEA	Tokai	D_2O(tank) H_2O(pool)	U UO_2 UAl_X-Al U_3Si_2-Al	Natural 1.5% 20% 20%	10MW 10MW 20MW 20MW	1963. 9 1972.1 1990.3 1999.9
KUR	KURRI	Kumatori	H_2O(tank)	U_3Si_2-Al	20%	5MW 5MW	1964.6 1991.4
JRR-4	JAEA	Tokai	Various multi-core	U-Al U_3Si_2-Al	93% 20%	3.5MW 3.5MW	1965. 1 1998. 7
JMTR	JAEA	Oarai	H_2O(MTR)	U-AL UAl_X-Al U_3Si_2-Al	93% 45% 20%	50MW 50MW 50MW	1968. 3 1986.7 1994.1
YAYOI	Tokyo University	Tokai	Fast(horizontal ly movable)	U	93%	2kW	1971.4
NSRR	JAEA	Tokai	H_2O(TRIGA)	U-ZrH	20%	300kW	1975.6
HTTR	JAEA	Oarai	Graphite-He (gas)	UO_2 particle	9.9% (Max)	30MW	2002.3

Table 3. Japanese Critical Assemblies in Operation

Name	Owner	Site	Type and enrichment			Max. Power	Start-up date
TCA	JAEA	Tokai	H_2O(tank)	UO_2 UO_2-PuO_2	2.6% 4%	200W	1962. 8
NCA	Toshiba	Kawasaki	H_2O(tank)	UO_2	1-5%	200kW	1963. 12
FCA	JAEA	Tokai	Fast Horizontally Split	U U Pu	93% 20%	2kW	1967. 4
KUCA	KURRI	Kumatori	Various multi-core	U-Al UAl_X	93% 45%	100W 1kW(short time)	1974. 8 1981. 5
STACY	JAEA	Tokai	Homogeneous Heterogeneous Tank type	U Pu	4, 6, 10%	200W	1995. 2
TRACY	JAEA	Tokai	Homogeneous Tank type	U	10%	10kW $5x10^9$W (transient)	1995.12

Table 4. Research Reactors Relevant to RERTR in Japan

Name	Power(MW)	First Critical	Fuel Enrichment	Conversion
KUR(KURRI)	5	1964	HEU-LEU	2009*
KUHFR(KURRI)	30	canceled		
JRR-3(JAEA)	20	1962	LEU-LEU	1990
JRR-4(JAEA)	3.5	1965	HEU-LEU	1998
JMTR (JAEA)	50	1968	MEU-LEU	1994
Related Critical Assembly				
KUCA(KURRI)	0.0001	1974	HEU-MEU	1981

*** Operation using HEU terminated; full core conversion expected by March 2009**

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