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CURRENT STATUS OF REDUCED ENRICHMENT PROGRAM FOR RESEARCH REACTORS IN JAPAN

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ABSTRACT

The status of research and test reactors relevant to RERTR program in Japan is described. Among the research reactors and critical assemblies in operation in Japan, those concerned with the RERTR program are the JRR-3M, JRR-4 and JMTR of Japan Atomic Energy Agency (JAEA) and KUR of Kyoto University Research Reactor Institute (KURRI). Reduced enrichment programs for the JRR-3M, JRR-4 and JMTR of JAEA has been completed by 1999, and the reactors are being satisfactory operated using LEU fuels. In JAEA, a new committee, "Committee on Nuclear Fuel for Research and Test Reactors" has been launched in 2008 in order to study about procurement of new fuel and treatment of spent fuel. In KURRI, the KUR is in the conversion stage since its termination of operation with HEU on February 2006. Due to the delay in the LEU fuel transportation, the full core conversion of KUR to LEU fuel has been postponed from its original schedule and is now expected to be achieved by the end of FY2009.

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 since 1971 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. Since then, basic studies on fuel conversion as well as actual core conversion has been promoted as 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.

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

1977. 11	Japanese Committee on INFCE WC-8 was started. 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	HEU	1W	1961. 11
JRR-3	JAEA	Tokai	D_2O(tank) H_2O(pool)	U UO_2 UAl_X-Al U_3Si_2-Al	Natural LEU LEU LEU	10MW 10MW 20MW 20MW	1963. 9 1972.1 1990.3 1999.9
KUR	KURRI	Kumatori	H_2O(tank)	U_3Si_2-Al	LEU	5MW 5MW	1964.6 1991.4
JRR-4	JAEA	Tokai	Various multi-core	U-Al U_3Si_2-Al	HEU LEU	3.5MW 3.5MW	1965. 1 1998. 7
JMTR	JAEA	Oarai	H_2O(MTR)	U-AL UAl_X-Al U_3Si_2-Al	HEU HEU LEU	50MW 50MW 50MW	1968. 3 1986.7 1994.1
YAYOI	Tokyo University	Tokai	Fast(horizontally movable)	U	HEU	2kW	1971.4
NSRR	JAEA	Tokai	H_2O(TRIGA)	U-ZrH	LEU	300kW	1975.6
HTTR	JAEA	Oarai	Graphite-He (gas)	UO_2 particle	LEU	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	LEU LEU	200W	1962. 8
NCA	Toshiba	Kawasaki	H_2O(tank)	UO_2	LEU	200kW	1963. 12
FCA	JAEA	Tokai	Fast Horizontally Split	U U Pu	HEU LEU	2kW	1967. 4
KUCA	KURRI	Kumatori	Various multi-core	U-Al UAl_X	HEU HEU	100W 1kW(short time)	1974. 8 1981. 5
STACY	JAEA	Tokai	Homogeneous Heterogeneous Tank type	U Pu	LEU	200W	1995. 2
TRACY	JAEA	Tokai	Homogeneous Tank type	U	LEU	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*
JRR-3(JAEA)	20	1962	LEU-LEU	1990
JRR-4(JAEA)	3.5	1965	HEU-LEU	1998
JMTR (JAEA)	50	1968	MEU-LEU	1994

***Operation of KUR using HEU terminated; full core conversion under progress**

**** KUCA (Kyoto University Critical Assembly) has been used for neutronic studies of MEU (approx. 45% enriched) fuel during 1980s under joint study program with ANL**

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 was 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 aluminides (UAl_X-Al) to silicides (U_3Si_2-Al) in September 1999 in order to reduce the amount of spent fuel. Uranium density of the silicides fuel is about 4.8Ug/cm^3, and cadmium wires are inserted in each both side plate of fuel element as burnable absorber. The silicides fuel core has 1.6 times as much uranium as that of the aluminides 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 59,900 MWD in July 2009 at the last operation cycle.

(2) JMTR

The JMTR is a testing reactor dedicated to the irradiation test of materials and fuels. It achieved first criticality in March 1968. The JMTR has been operated at thermal power of 50MW, and utilized for the irradiation experiments of fuels and materials, as well as for radioisotope production. The JMTR was completely converted to LEU fuel in January 1994. The LEU fuel is silicides fuel (U_3Si_2-Al) with 4.8gU/cm^3, and cadmium wires are inserted into side plates of fuel elements. A long-term continuous operation became possible by the conversion of its core to the LEU with high density uranium. The JMTR has been well operated with LEU fuel since 1994, and reached 166,612.8 MWD in August 2006 at the last operation cycle.

The reactor facilities are being refurbished during four years from the beginning of FY2007, and the refurbishment works are in progress as scheduled. The refurbishment of JMTR is promoted by two projects, “replacement of reactor components” and “construction of new irradiation facilities”. The renewed JMTR will be started from FY 2011, and operated for a period of about 20 years (until around FY2030). After reoperation, JMTR will contribute to many fields, such as the lifetime extension of LWRs, expansion of industrial use, progress of science and technology.

(3) JRR-4

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 silicides fuel (U_3Si_2-Al) was achieved in July 1998. Uranium density of the silicides 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 October 2009.

3.2 Research Reactor Institute, Kyoto University (KURRI)

The Kyoto University Research Reactor (KUR, 5MW) has been operated since 1964 using HEU fuel. Conversion to LEU fuel started from 1992 as a partial core conversion, and two LEU silicide fuel elements have been loaded to the core in May, 1992. These were the first LEU silicide fuel elements loaded and used in Japanese research reactor. In 1994, the U. S. Government gave an approval to utilize the HEU fuel material prepared for Kyoto University High Flux Reactor (KUHFR) project[1] to be used in the KUR. Since then, the KUR continued its operationwith HEU until February 23, 2006.

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. 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, which opened the LEU path for KUR. The safety review for the full core conversion to LEU silicide fuel has completed in February 2008. The fabrication of LEU fuel element is terminated and the fuel elements are currently awaiting the transportation schedule to be fixed. The completion of full core conversion of KUR to LEU is expected to be achieved by the end of FY2009.

4. Spent fuel management in Japan

4.1 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.

With regard to the shipment of spent fuels to the U.S., a new contract with US DOE was concluded in autumn 2008. The first transportation of spent fuel elements by the new contract is planned to be carried out by the end of 2009.

4.2 Spent Fuel Management in KURRI

The shipment of HEU spent fuel of KUR under the U.S. FRR SNF Acceptance Program has commenced at 1999. All (seven) shipments have been successfully terminated as scheduled, so the HEU spent fuel removal from KUR has successfully completed.

5. Relevant Topics in JAEA

In 2008 JAEA newly established a Committee on Countermeasure for Nuclear Fuel for Research and Test Reactors in order to deliberate important issues such as procurement of new fuel and treatment of spent fuel. With regard to shipment of spent fuel a new contract between the US DOE and JAEA based on the FRR SNF Acceptance program was concluded on 15th

[1] The KUHFR project has been officially cancelled in 1991.

October 2008. Two sub-committees under the Committee are studying feasibility of U-Mo fuel and treatment of spent fuel, respectively. The subcommittee concerning the processing of spent fuel investigated reasonable processing of LEU plate type fuel of research reactors. Discussions were carried out from the viewpoint of technology, cost and safety on such ways as storage, once through, reprocessing and shipping to U.S. under the FRR SNF program. The Committee acknowledges continuance of the FRR SNF Acceptance program as very important.

6. Summary

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

7. Acknowledgements

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