

**STATUS OF REDUCED ENRICHMENT PROGRAM
FOR RESEARCH REACTORS IN JAPAN**

Keiji Kanda and Yoshihiro Nakagome
Research Reactor Institute, Kyoto University
Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan
Phone: +81-724-53-2145
Fax: +81-724-51-2604

Keisuke Kaieda, Osamu Baba and Harumichi Tsuruta
Japan Atomic Energy Research Institute
Uchisaiwai-cho, Chiyoda-ku, Tokyo 100-0011, Japan
Phone: +81-3-3592-2361
Fax: +81-3-3592-2199

Presented at the
1998 International Meeting on Reduced Enrichment
for Research and Test Reactors

October 18-23, 1998
Sao Paulo, Brazil

STATUS OF REDUCED ENRICHMENT PROGRAM FOR RESEARCH REACTORS IN JAPAN

Keiji Kanda and Yoshihiro Nakagome
Research Reactor Institute, Kyoto University
Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan
Phone: +81-724-53-2145
Fax: +81-724-51-2604

Keisuke Kaieda, Osamu Baba and Harumichi Tsuruta
Japan Atomic Energy Research Institute
Uchisaiwai-cho, Chiyoda-ku, Tokyo 100-0011, Japan
Phone: +81-3-3592-2361
Fax: +81-3-3592-2199

ABSTRACT

The reduced enrichment programs for the JRR-3M, JRR-4 and JMTR of Japan Atomic Energy Research Institute (JAERI) has been completed. The KUR of Kyoto University Research Reactor Institute (KURRI) has been partially completed and is still in progress under the Joint Study Program with Argonne National Laboratory (ANL).

The operation of the upgraded JRR-4 started in October, 1998 with LEU silicide fuels.

The Japanese Government approved a cancellation of the KUHFRR Project in February 1991, and April 1994 the U.S. Government gave an approval to utilize HEU fuel in the KUR instead of the KUHFRR. Therefore, the KUR will be operated with HEU fuel until March 2004, then the full core conversion with LEU silicide will be done.

INTRODUCTION

Among eighteen research reactors and critical assemblies in operation in Japan (Tables 1 and 2), those which are relevant to the RERTR program are the JRR-3M, JRR-4 and JMTR of JAERI and KUR of KURRI (Table 3). The JRR-2 was shutdown in 1996. The RERTR program in Japan has been pursued extensively under the direction of the Five Agency Committee on Highly Enriched Uranium, which consists of the Science and Technology Agency, the Ministry of Education, Science and Culture, the Ministry of Foreign Affairs, JAERI and KURRI, which is held every three months¹⁻¹⁵ (Table 4). It has played a remarkable role in deciding policies related to the program, and the 83rd Committee was held in August 1998. Recently, reprocessing of spent fuel has been mainly discussed.

Table 1. Japanese Research Reactors in Operation

Name	Owner	Site	Type and enrichment			Max. Power	Start-up date
UTR KINKI	Kinki University	Higashi-osaka	H ₂ O(UTR)	U-Al	90%	1W	1961. 11
TRIGA-II RIKKYO	Rikkyo University	Yokosuka	H ₂ O(TRIGA)	U-ZrH	20%	100kW	1961. 12
TTR-1	Toshiba	Kawasaki	H ₂ O(pool)	U-Al	20%	100kW	1962. 3
JRR-3M	JAERI	Tokai	D ₂ O(tank)	U	Natural	10MW	1963. 9
			H ₂ O(pool)	UO ₂	1.5%	10MW	1972. 1
				UAl _x -Al	20%	20MW	1990. 3
MuITR	Musashi Inst. Tech.	Kawasaki	H ₂ O(TRIGA)	U-ZrH	20%	100kW	1962. 3
KUR	KURRI	Kumatori	H ₂ O(tank)	U-Al	93%	5MW	1964. 6
				U ₃ Si ₂ -Al	20%	5MW	1991. 4
JRR-4	JAERI	Tokai	H ₂ O(pool)	U-Al	93%	3.5MW	1965. 1
				U ₃ Si ₂ -Al	20%	3.5MW	1998.7
JMTR	JAERI	Oarai	H ₂ O(MTR)	U-Al	93%	50MW	1968. 3
				UAl _x -Al	45%	50MW	1986. 7
				U ₃ Si ₂ -Al	20%	50MW	1994. 1
YAYOI	University of Tokyo	Tokai	fast(horizontally movable)	U	93%	2kW	1971. 4
NSRR	JAERI	Tokai	H ₂ O(TRIGA)	U-ZrH	20%	300kW	1975. 6

Table 2. Japanese Critical Assemblies in Operation

Name	Owner	Site	Type and enrichment			Max. Power	Start-up date
TCA	JAERI	Tokai	H ₂ O(tank)	UO ₂ UO ₂ -PuO ₂	2.6% 4%	200W	1962. 8
NCA	Toshiba	Kawasaki	H ₂ O(tank)	UO ₂	1-5%	200kW	1963. 12
FCA	JAERI	Tokai	fast horizontally split	U U Pu	93% 20%	2kW	1967. 4
DCA	PNC	Oarai	D ₂ O(tank)	UO ₂ UO ₂ -PuO ₂	1.2% 1.5%	1kW	1969. 12
KUCA	KURRI	Kumatori	various multi-core	U-Al UAl _x	93% 45%	100W 1kW (short time)	1974. 8 1981. 5
VHTRC	JAERI	Tokai	Graphite horizontally split	U	2,4,6%	10W	1985. 5
STACY	JAERI	Tokai	Homogeneous Heterogeneous Tank type	U Pu	4,6,10%	200W	1995. 2
TRACY	JAERI	Tokai	Homogeneous Tank type	U	10%	10kW 5x10 ⁹ W (transient)	1995. 12

Table 3. Research Reactor Relevant to RERTR in Japan

Name	Power(MW)	First Critical	Fuel Enrichment	Conversion
KUR(KURRI)	5	1964	HEU-LEU	2004
KUHFR(KURRI)	30	canceled		
JRR-3M(JAERI)	20	1962	LEU-LEU	1990
JRR-4(JAERI)	3.5	1965	HEU-LEU	1998
JMTR(JAERI)	50	1968	MEU-LEU	1994
Related Critical Assembly				
KUCA(KURRI)	0.0001	1974	HEU-MEU	1981

Table 4. 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 U_{Al_x} -Al full core experiment was started in the KUCA.
1983. 3	ANL-KURRI Phase B was completed.
1983. 8	MEU U_{Al_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 1 LEU U_{Al_x} -Al full size elements in the JRR-2 was started.
1984. 10	Irradiation of LEU U_{Al_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 was performed.
1985. 1	Irradiation of MEU U_{Al_x} -Al full size elements in the JMTR was started.
1985. 3	Irradiation of MEU U_{Al_x} -Al full size elements in the JMTR was completed. Irradiation of LEU U_xSi_y -Al miniplates in the JMTR was started.
1985. 6	Irradiation of LEU U_xSi_y -Al miniplates in the JMTR was completed.
1985. 10	Neutronics calculations for the KUR core conversion from HEU to LEU was performed.
1986. 1	Irradiation of MEU U_{Al_x} -Al full size elements in the JRR-2 was started.
1986. 5	Irradiation of MEU U_{Al_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 U_{Al_x} -Al full core in the JRR-2 was started.
1988. 7	PIE of MEU, LEU U_{Al_x} -Al full size elements in the JRR-2 was completed.
1988. 12	Irradiation of a LEU U_{Al_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 ₃ Si ₂ -Al elements were inserted into the KUR core.
1993. 11	Two LEU U ₃ Si ₂ -Al elements were inserted into the JMTR core.
1994. 1	The JMTR was fully converted from MEU to LEU with U ₃ Si 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 fully converted from HEU to LEU with U ₃ Si ₂ -Al fuel.

JAERI

JRR-3M

The JRR-3M achieved its first criticality in March 1990 using LEU aluminide fuel (2.2gU/cm³). Since November 1990, the JRR-3M has been operated for capsule irradiation, beam experiments and so on at the reactor power of 20MW. One operational cycle consists of four weeks of full power operation and one week of shutdown for refueling, irradiation capsule handling and maintenance.

The JRR-3M has been planned to fully convert to LEU silicide fuel (4.8gU/cm³) in 1999 so as to decrease the number of spent fuels generated in a year. The safety review for the use of LEU silicide fuel was submitted to competent authority in September 1996, and was completed in the last January.

JRR-4

The JRR-4 had been operated using HEU (93% enriched uranium) fuels since 1965. The JRR-4 had consumed all of the HEU fuels and finished operation using them on January 1996. And the JRR-4 modification works had started. The modification works, which deal with fuel conversion, installation of a medical irradiation facility and etc., had successfully completed in June 1998. The JRR-4 reached the first criticality using LEU silicide fuel (3.8gU/cm³) on the 14 July 1998 and performance test was successfully completed.

JMTR

The Japan Materials Testing Reactor (JMTR) was completely converted to the LEU fuel in January 1994. The LEU fuel is a silicide fuel (U₃Si₂) with 4.8gU/cm³, and burnable absorber of cadmium wires are placed in each side plate of fuel element. The silicide fuel allowed an extension of JMTR operating days without refueling that has been taken a 26-day operation from a 12-day operation by high enrichment uranium fuel core.

After the core conversion, 260 LEU fuel elements have been used in JMTR without any trouble until July 1998.

Spent Fuel Management

Spent fuels from JRR-2, JRR-3M, JRR-4, JMTR and JMTRC are stored in their storage facilities. They will be shipped to U.S.A under the U.S. spent fuel acceptance policy of foreign

research reactors. Two shipments of JAERI have been successfully completed since 1997. Renewal of cask license to be needed is a primary concern for the next shipment.

KURRI

The Kyoto University Research Reactor (KUR, 5MW) has been operated since 1964 using HEU fuel. The KUR has been still utilized for boron neutron capture therapy. Since February 1990, 61 patients of cancer were treated by nine chief medical doctors of five groups. In order to increase the number of patients, the upgrade of the KUR Heavy Water Facility was completed. The main improvement of facility is (1) to realize an epithermal neutron field in addition to thermal neutrons, and (2) to irradiate patients during continuous operation of the KUR, which were licensed in June 1998.

According to the government policy, Kyoto University tried to convert the KUR to use the LEU fuel, and already two LEU silicide fuel elements have been inserted to the core in May 1992. The KUR will be operate with HEU fuel until March 2004.

As to spent fuel, two casks are under fabrication. The first shipment will be done in Fiscal 1999.

TRIGA FUEL

The Rikkyo University TRIGA II reactor will be shut down, and its spent fuel be return to US. In June 1998, Rikkyo University made a contact to fabricate a cask similar to the JMTR and the KUR fuels. Shipment may be done in not earlier than Fiscal 2000.

Musashi Institute of Technology also has a TRIGA II reactor. No decision related its spent fuel has be done yet.

REFERENCES

1. K. Kanda, "Reducing Enrichment Program for Research Reactors in Japan", in Proceedings of the International Meeting of Research and Test Reactor Core Conversion from HEU to LEU Fuels, Argonne, USA, November 8-10, ANL/RERTR/TM-4 CONF-821155, pp.24-32.
2. K. Sato, "Opening Statement of the International Meeting on Reduced Enrichment for Research and Test Reactors", in Proceedings of the International Meeting on Reduced Enrichment for Research and Test Reactors, Tokai, Japan, October 24-27, 1983, JAERI-M 84-073, pp.8-10 (May 1984).
3. K. Kanda, T. Shibata, I. Miyanaga, H. Sakurai and M. Kanbara, "Status of Reduced Enrichment Program for Research Reactor Fuels in Japan", in Proceedings of International Meeting of Reduced Enrichment of Research and Test Reactors, Argonne, USA, October 15-18, 1984, ANL/RERTR/TM-6 CONF-8410173, pp.11-20 (July 1985).
4. I. Miyanaga, K. Kamei, K. Kanda and T. Shibata, "Present Status of Reduced Enrichment Program for Research and Test Reactor Fuels in Japan", in Reduced Enrichment for Research and Test Reactors, Proceedings of an International Meeting, Petten, The Netherlands, October 14-16, 1985, D. Reidel Publishing Company, Dordrecht/Boston/Lancaster/Tokyo, pp.21-32

(March 1986).

5. K. Kanda, T. Shibata, Y. Iso, H. Sakurai and Y. Okamoto, "Status of Reduced Enrichment Program for Research and Test Reactor Fuels in Japan", in Proceedings of the 1986 International Meeting on Reduced Enrichment for Research and Test Reactors, Gatlinburg, USA, November 3-6, 1986, ANL/RERTR/TM-9 CONF-861185, pp.14-22.
6. Y. Futamura, H. Sakurai, Y. Iso, K. Kanda and I. Kimura, "Status of Reduced Enrichment Program for Research and Test Reactor Fuels in Japan", in Proceedings of the 10th RERTR Meeting, CNEA, Buenos Aires, Argentina, September 28 - October 1, 1987, pp.22-31.
7. K. Kanda, H. Nishihara, Y. Futamura, H. Sakurai and Y. Iso, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of the 11th RERTR Meeting, San Diego, USA, September 19-22, 1988, ANL/RERTR/TM-13 CONF-8809221, pp.31-38.
8. Y. Futamura, M. Kawasaki, Y. Iso, K. Kanda and M. Utsuro, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of the 1990 International Meeting on Reduced Enrichment for Research and Test Reactors, Newport, USA, September 23-27, 1990, ANL/RERTR/TM-18 CONF-9009108, pp.16-24.
9. K. Kanda, H. Nishihara, Y. Futamura, M. Kawasaki and T. Asaoka, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of the 1990 International Meeting on Reduced Enrichment for Research and Test Reactors, Newport, USA, September 23-27, 1990, ANL/RERTR/TM-18 CONF-9009108, pp.16-24.
10. Y. Futamura, M. Kawasaki, T. Asaoka, K. Kanda and H. Nishihara, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of the 14th RERTR Meeting, Jakarta, Indonesia, November 4-7, 1991, pp.23-31.
11. K. Kanda, H. Nishihara, Y. Futamura, E. Shirai and T. Asaoka, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of 15th RERTR Meeting, Roskilde, Denmark, September 27 - October 1, 1992, pp.12-21.
12. M. Saito, E. Shirai, K. Sanokawa, K. Kanda and H. Nishihara, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of the 16th RERTR Meeting, Oarai, Japan, October 4-7, 1993, JAERI-M94-042, pp.14-22 (March 1994).
13. K. Kanda, H. Nishihara, E. Shirai, R. Oyamada and K. Sanokawa, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of the 1994 International Meeting on RERTR, Williamsburg, USA, September 18-23, 1994, in press.
14. N. Ohnishi, R. Oyamada, K. Sanokawa, K. Kanda and Y. Nakagome, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of the XVIII International Meeting PARIS, September 17-21, 1995.
15. K. Kanda, Y. Nakagome, M. Isshiki, O. Baba and H. Tsuruta, "Status of Reduced Enrichment Program for Research Reactors in Japan", in Proceedings of the 19th International Meeting on RERTR, Seoul, Korea, October 7-10, 1996, pp.34-41.