STATUS OF REDUCED ENRICHMENT PROGRAM FOR RESEARCH REACTORS IN JAPAN

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ABSTRACT

The status of reduced enrichment program for research reactors in Japan will be reviewed. The reduced enrichment programs for the JRR-3M, JRR-4 and JMTR of Japan Atomic Energy Agency (JAEA, former name is Japan Atomic Energy Research Institute (JAERI)) has been completed by 1999, and the reactors are being satisfactory operated using LEU fuels. 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 JRR-3M using LEU silicide fuel elements have done a functional test by the Japanese Government in 2000, and the property of the reactor core was satisfied.

JAEA has established a "U-Mo fuel ad hoc committee" and has been studying the U-Mo fuel installation plan by carefully observing the development situation of the U-Mo fuel.

In KURRI, the KUR has terminated its operation using HEU fuel on February 2006. The HEU KUR spent fuel elements will be sent to the U.S. by March 2008. Licensing for the full core conversion of KUR to LEU fuel is under progress and the core conversion to LEU is expected to be completed in 2008.

1. Introduction

1. Introduction

Among fourteen research reactors and critical assemblies in operation in Japan, which are listed in Tables 1 and 2, those concerned with the RERTR program are the JRR-3M, JRR-4 and JMTR of The Japan Atomic Energy Agency (JAEA) and KUR of Kyoto University Research Reactor Institute (KURRI). These research reactors are shown in Table 3. In JAEA, the High Temperature Engineering Test Reactor (HTTR), which uses LEU fuel, reached the first criticality in November, 1998, and a full power test was completed in 2001.

The RERTR program in Japan had been pursued extensively under the direction of the Five Agency Committee on Highly Enriched Uranium, which consisted of the Science and Technology Agency (STA), the Ministry of Education, Science and Culture (MOE), the Ministry of Foreign Affairs, JAERI and KURRI, which was held every three months [1-23]. It had played a remarkable role in deciding policies related to the program, and the 92nd Committee was held in December, 2000. After this meeting, MOE and STA were joined as one Ministry (Ministry of Education, Culture, Sports, Science and Technology : MEXT) under the administrative reorganization policy in January, 2001. However, the Committee has not opened after MEXT started. The history of RERTR program in Japan is tabulated in Table 4.

Table 1. Japanese Research Reactors in Operation

Name	Owner	Site	Type and enrichment			Max.Power	Start-up date
UTR KINKl	Kinki University	Higashi-osaka	H_2O(UTR)	U-Al	90%	1W	1961.11
JRR-3M	JAEA	Tokai	D_2O(tank) H_2O(pool)	U UO_2 UAlx-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-Al U_3Si_2-Al	93% 20%	5MW 5MW	1964.6 1991.4
JRR-4	JAEA	Tokai	H_2O(pool)	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	University of Tokyo	Tokai	fast(horizontally 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 2. 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	6,10%	200W	1995. 2
TRACY	JAEA	Tokai	Homogeneous Tank type	U	10%	10kW $5x10^9$W (transient)	1995.12

Table 3. Research Reactors Relevant to RERTR in Japan

Name	Power(MW)	First Critical	Fuel Enrichment	Conversion
KUR(KURRI)	5	1964	HEU-LEU	(2006-2008)*
KUHFR(KURRI)	30	canceled		
JRR-3M(JAEA)	20	1962	LEU-LEU	1990
JRR-4(JAEA)	3.5	1965	HEU-LEU	1998
JMTR (JAEA)	50	1968	MEU-LEU	1994

* Operation using HEU terminated; full conversion to LEU expected in FY2008

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 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℃.
2006.8	The JMTR was temporarily shut down to modify the irradiation facilities

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

2.1 Japan Atomic Energy Agency (JAEA)

(1) JRR-3M

The JRR-3M was fully converted to LEU silicide fuel (4.8gU/cm^3) with cadmium wires of burnable absorber in September, 1999 so as to decrease the number of spent fuels generated in a year.

After converted to LEU silicide fuel in September, 1999, the JRR-3M has a lot of beam researches and users, many papers were also released so far, and no special problem related fuel was occurred.

(2) JRR-4 and JMTR

JRR-4 and JMTR are in very good condition for operation after the conversion to LEU silicide fuels.

The JMTR was completely converted to the LEU fuel in January, 1994. The LEU fuel is a silicide fuel (U_3Si_2) with 4.8gU/cm^3, and burnable absorber of cadmium wires is placed in each side plate of fuel element. The LEU silicide fuels allowed an extension of JMTR operating days without refueling that has been taken a 26-day operation from a 12-day operation by HEU fuels core.

After the conversion, the LEU fuel elements have been used in JMTR without any trouble related fuel until August, 2006.

The JMTR experienced to stop operation so often due to functional problems, then a re-evaluation taskforce was started in 2003, and the report of the taskforce was submitted to President of JAEA. The JMTR was temporarily shut down in August, 2006 to modify the irradiation facilities mainly, and an operation plan after 2006 will be studied deeply until 2009.

(3) Spent Fuel Management

Spent fuel elements from JRR-3M, JRR-4, JMTR and JMTRC are stored in their storage facilities. And these spent fuels will be shipped to U.S. under the Foreign Research Reactor Spent Nuclear Fuel Acceptance (FRRSNFA) Program of U.S., and nine shipments have been successfully carried out since 1997.

In March, 2007, JAEA shipped 180 spent fuel elements (120 elements for JMTR, 20 for JMTRC and 40 for JRR-3) to USA. JAEA is going to amend the current contract according to the extension of the FRRSNFA Program.

2.2 Research Reactor Institute, Kyoto University (KURRI)

The Kyoto University Research Reactor (KUR, 5MW) has been operated since 1964 using HEU fuel. Especially, the KUR has been extensively utilized for boron neutron capture therapy (BNCT). Since February, 1990, over 300 patients of cancer were treated by ten chief medical doctors of six groups. In order to increase the number of patients, the upgrade of the KUR Heavy Water Facility was completed. The main improvement of the 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. Recently, treatment of head and neck cancer patients is increasing in addition to brain tumor and melanoma, and treatment of lung cancer and liver cancer patients has started.

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 1991, the Japanese Government approved cancellation of the Kyoto University High Flux Reactor (KUHFR) project. In 1994, the U. S. Government gave an approval to utilize HEU fuel in the KUR instead of the KUHFR, since Kyoto University already prepared HEU fuel for KUHFR. Therefore, the KUR has been operating with HEU until February 23, 2006.

Kyoto University has a strong intention to continue the KUR operation with LEU fuel after 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. It should be noted that the Record of Decision (ROD) concerning ten-year extension of FRRSNFA program issues by the U.S. DOE in November, 2004 was very important for the KUR operation with LEU after 2006. According to this extension, Kyoto University has made a conclusion of new contract concerning the FRRSNFA program with the USDOE in February 2006, and the safety review for the use of LEU silicide fuel in the core has commenced in 2007 and is under progress. The completion of full core conversion of KUR to LEU is expected to be in FY 2008.

As to spent fuel, six shipments were hitherto successfully conducted under the U.S. FRRSNFA program. The final shipment of the remaining KUR spent fuel elements produced in the KUR operation with HEU fuel is under preparation and will be terminated by March, 2008.

2.3 Other Research Reactor Facilities

The Rikkyo University TRIGA Mark II reactor (100kW) was shut down in 2002 and its spent fuel was sent back to U.S. in 2003.

The TTR (100kW) spent fuels of Toshiba Company was also sent to the U.S. in 2003.

Musashi Institute of Technology also has a TRIGA Mark II reactor (100kW) and its spent fuel was sent back to the U.S. in 2007.

3. Conclusions and Acknowledgements

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

References

[1] K. Kanda, "Reducing Enrichment Program for Research Reactors in Japan", Proceedings of the International Meeting of Research and Test Reactor Core Conversion from HEU to LEU Fuels, Argonne, USA, November 8-10, 1982, 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", 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", 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", 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", 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", 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", Proceedings of the 1lth 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", Proceedings of the 12th RERTR Meeting, West Berlin, FRG, September 10-14, 1989, KFA Julich, 1991, pp.21-28.

[9] K. Kanda, H. Nishihara, Y. Futamura, M. Kawasaki and T. Asaoka, “Status of Reduced Enrichment Program for Research Reactors in Japan", 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", 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", Proceedings of 15th RERTR Meeting, Roskilde, Denmark, September 27 - October 1, 1992, pp.12-21.

[12] M. Sato, E. Shirai, K. Sanokawa, K. Kanda and H. Nishihara, "Status of Reduced Enrichment Program for Research Reactors in Japan", 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", Proceedings of the 1994 International Meeting on RERTR, Williamsburg, USA, September 18-23, 1994.

[14] N. Ohnishi, R. Oyamada, K. Sanokawa, K. Kanda and Y. Nakagome, "Status of Reduced Enrichment Program for Research Reactors in Japan", 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", Proceedings of the 19th International Meeting on RERTR, Seoul, Korea, October 7-10, 1996, pp.34-41.

[16] K. Kanda, Y. Nakagome, M. Kaieda, O. Baba and H. Tsuruta, "Status of Reduced Enrichment Program for Research Reactors in Japan", Proceedings of the 21st International Meeting on RERTR, Sao Paulo, Brazil, October 18-23, 1998.

[17] K. Kaieda, O. Baba, Y. Nagaoka, K. Kanda, and Y. Nakagome, “Status of Reduced Enrichment Program for Research Reactors in Japan”, Proceedings of the 22nd International Meeting on RERTR, Budapest, Hungary, October 3-8,1999.

[18] K. Kanda, Y. Nakagome, K. Kaieda, H. Takahashi and K. Shimizu, “Status of Reduced Enrichment Program for Research Reactors in Japan”, Proceedings of the 23rd International Meeting on RERTR, Las Vegas, USA, October 1-6, 2000.

[19] K. Shimizu and Y. Nakagome, “Status of Reduced Enrichment Program for Research Reactors in Japan”, Proceedings of the 24th International Meeting on RERTR, San Carlos de Bariloche, Argentina, November 4-8, 2002.

[20] Y. Nakagome and K. Shimizu “Status of Reduced Enrichment Program for Research Reactors in Japan”, Proceedings of 25th International Meeting on RERTR, Chicago, USA, October 5-11, 2003.

[21] K. Shimizu and Y. Nakagome “Status of Reduced Enrichment Program for Research Reactors in Japan”, Proceedings of 26th International Meeting on RERTR, Vienna, Austria, October 10-16, 2004.

[22] Y. Nakagome H. Unesaki and H. Sagawa “Status of Reduced Enrichment Program for Research Reactors in Japan”, Proceedings of 27th International Meeting on RERTR, Boston, USA, October 13-18, 2005.

[23] M. Kinase, H. Sagawa, Y. Nakagome and H. Unesaki, “Status of Reduced Enrichment Program for Research Reactors in Japan”, Proceedings of 28th International Meeting on RERTR, Cape Town, South Africa, October 29 - November 2, 2006.