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First Results of MC Type LTA and Fuel Elements Sipping Tests after Conversion in MARIA Reactor

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ABSTRACT

In scope of cooperation with US Argonne National Laboratory MARIA reactor underwent full core conversion from High Enriched Uranium fuel to Low Enriched type. This process ended in September 2014, when MARIA started operation only on LEU fuel. During preparation period two low enriched Lead Testing Assemblies manufactured by Areva-CERCA were transported to and then tested in MARIA reactor core. These tests lasted between August 2009 and January 2011. First LTA reached 5899 MWh (63%) burnup and the second one 4025 MWh (43%). After unloading the elements, post-irradiation sipping tests were conducted – results were within normal limits. In 2014, that is after three years after unloading the LTA's, sipping tests were repeated and results from MC002 were rather alarming – sudden increase in fission products activity was observed. Cause of this issue is still being investigated, but it pushed us to start full scale program of regular measurements of LTA's and MC type fuel elements. Results of said measurements are presented in the paper.

1. Introduction

MARIA reactor was primarily designed for operation on high enriched fuel with content of 80% 235U. In the period 1999-2003 there has been performed a conversion on fuel enriched to 36%. Then IEA has decided to utilize LEU silicide fuel with lower enrichment (19.75%) for conversion of the MARIA reactor. In 2005 the feasibility study for applying the silicide fuel (U_3Si_2) of 4.8 g/cm^3 density was commenced. This silicide fuel was qualified under the RERTR Program and used successfully in many western research reactors. Supplier of such fuel is the company Areva (CERCA). CERCA delivered to IAE one dummy fuel assembly (DFA) in May 2008 for hydraulic testing and two LTA's (Lead Test Assemblies) in July 2008. The proposed fuel has been tested to very high levels of burnup. 2009 is the beginning of LTA's irradiation, followed by inserting CERCA fuel and start of conversion in September 2012. After unloading the LTA's elements, post-irradiation sipping tests were conducted. In September 2014 core conversion has ended and MARIA reactor is now operating only on LEU fuel elements. Also in 2014, that is after three years after unloading the LTA's, sipping tests were repeated and results from one of them, namely MC002 were rather alarming – sudden increase in fission products activity was observed. This lead to construction of special stand and start of full scale

measurement program. Also FEIMS (Fuel Element Integrity Monitoring System) utilized in MARIA reactor was very helpful. Its indications shown that MC003 fuel element starts to show signs of increased FP activity levels [3].
This paper shows construction of MC type fuel as well as stand for performing sipping tests of MC type LEU fuel in sheath, also results of measurements are presented.

2. MC LEU fuel

Fuel meat used in MC fuel elements is uranium silicide dispersion U_3Si_2 (uranium/silicon alloy) in an aluminum matrix. Fuel enrichment is 19.75% 235U. MC low enriched type fuel consists of 15 curved fuel plates combined into 5 tubes (tube numbering remained the same as for MR Russian fuel, tube #1 is omitted in MC fuel element). Plates forming the fourth pipe (separator pipe) are longitudinally welded. There are two independent sets of connectors: internal, binding tubes #2 and #3, and external, binding tubes #5 and #6. Instead of tube #1 (fuel tube in MR type element) MC fuel element has an aluminum tube serving as filler [1][2].
Figure 1 shows the construction of MC type fuel element and table 1 presents basic characteristics of MC fuel.

Table 1 Basic characteristics of MC type fuel element.

No.	Parameter	Value
		MC-5/485
1.	Total length of fuel section	1315 mm
2.	Nominal length of fuel	1000 mm
3.	Fuel type	U_3Si_2 dispersion in Al
4.	Content of U-235 in section	(485 ± 5) g
5.	Fuel enrichment	19.75 %
6.	Uranium density in fuel layer	4.79 g/cm^3
7.	Weight content of U in fuel layer	73.5 %
8.	Cladding thickness	0.6 mm (min. 0.4)
9.	Fuel layer thickness in section	0.80 mm
10.	Heat exchange surface	1.29 m^2
11.	Water gaps between tubes	2.5 mm
12.	Inner gaps cross section	724 mm^2
13.	Outer gaps cross section	1361 mm^2
14.	Hydraulic diameter – inner	4.49 ÷ 4.71 mm
15.	Hydraulic diameter – outer	4.77 ÷ 4.82 mm

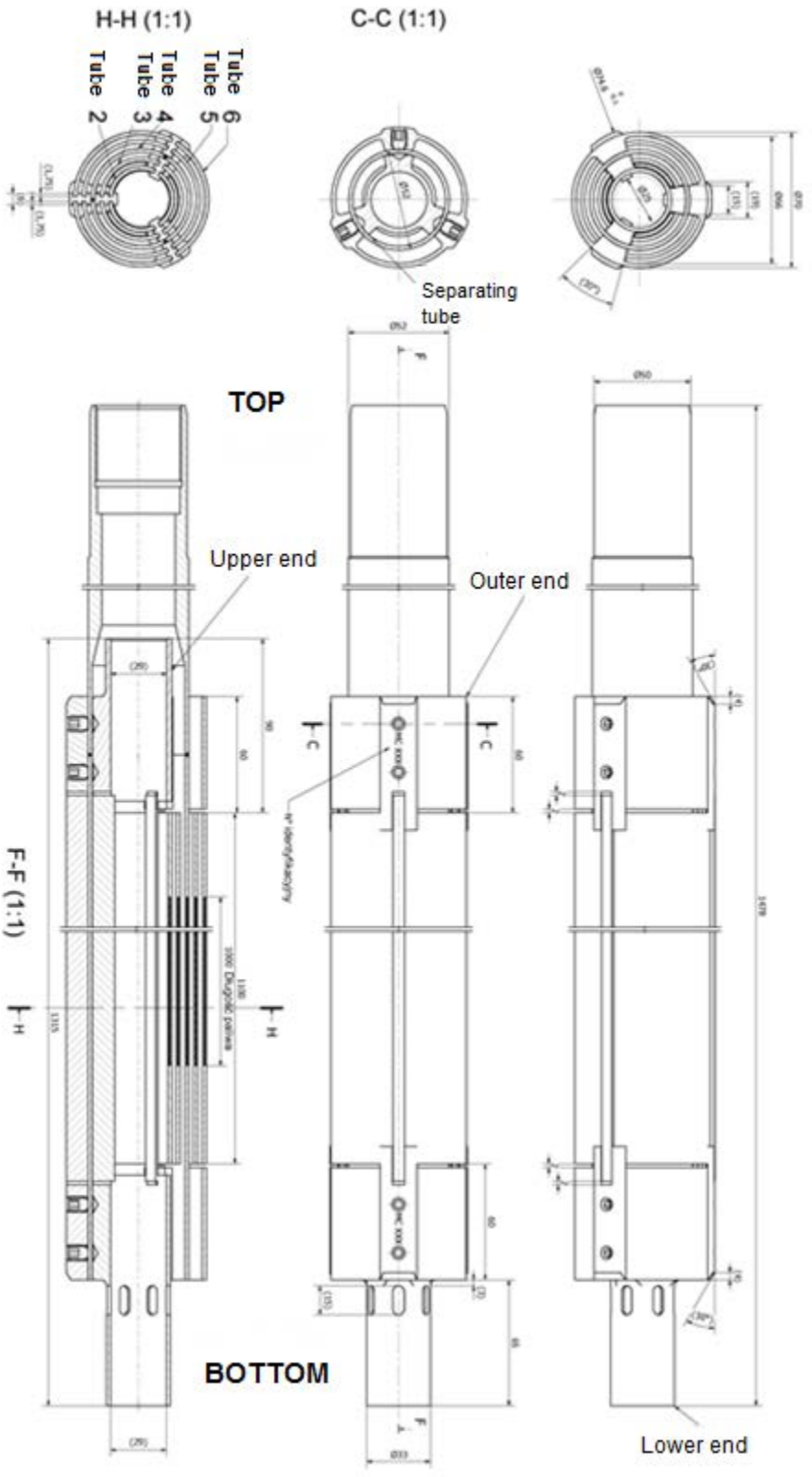

Figure 1. Diagram of MC type fuel element.

3. Construction of special stand to perform sipping tests of MC type LEU fuel in sheath

In scope of works appointed in cooperation between ANL and NCNR, project M536 “Stand for

measuring the release of fission products into water from spent fuel elements remaining in channels" was carried out.
Stand itself is a supporting structure attached to spent fuel pool wall. Along this structure measuring head is moving. Spent fuel element, remaining in fuel channel, is inserted into the stand above measuring head which initially stays at the bottom of spent fuel pool. After insertion of fuel element, measuring head is pulled up to top in order to mount and connect the wires to the on-ground part of the stand.
In figure 3 diagram of the stand is shown. Figures 4 and 5 shows view of stand mounted in MARIA reactor spent fuel pool.

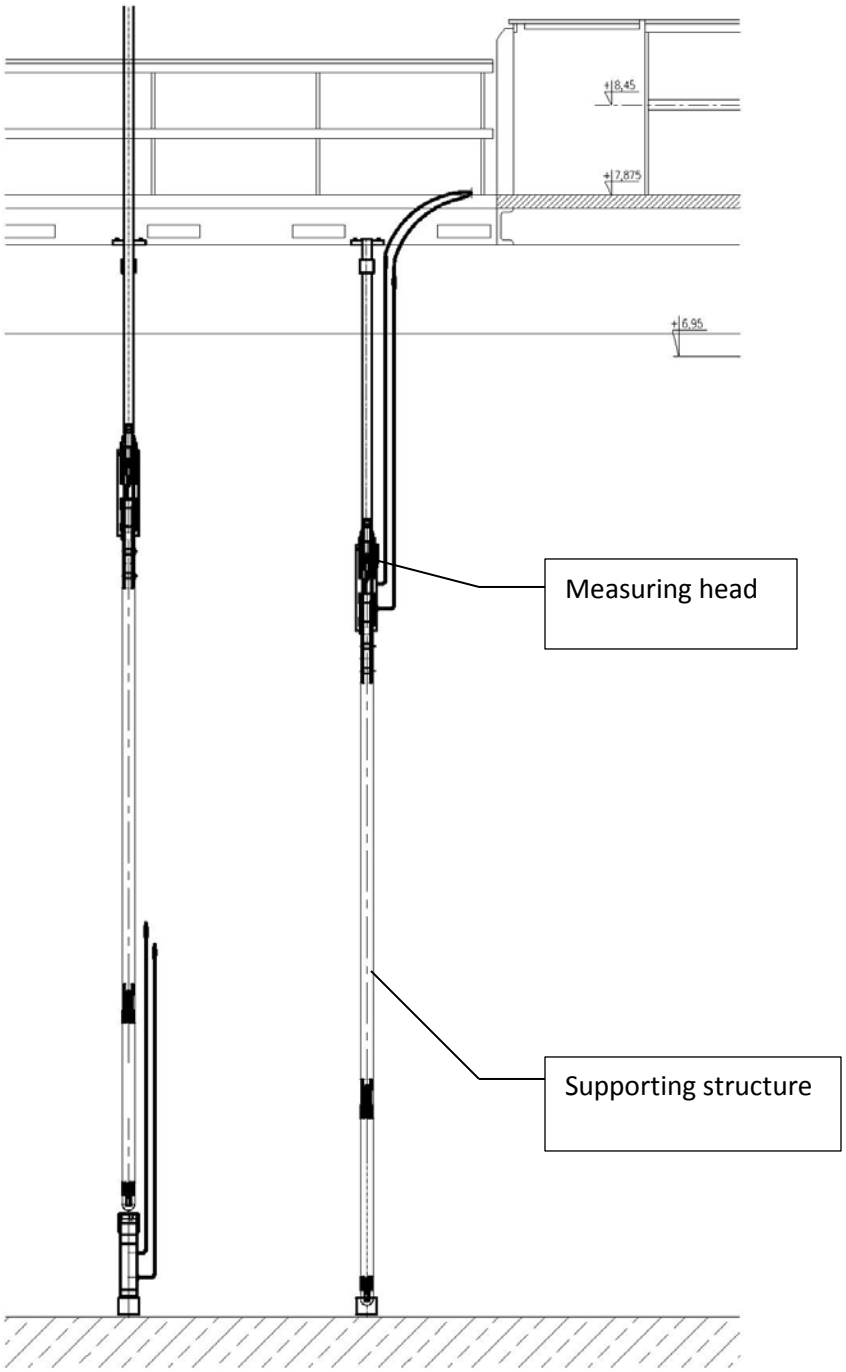

Figure 3 Diagram of the stand for measuring the release of fission products into water from spent fuel elements remaining in channels.

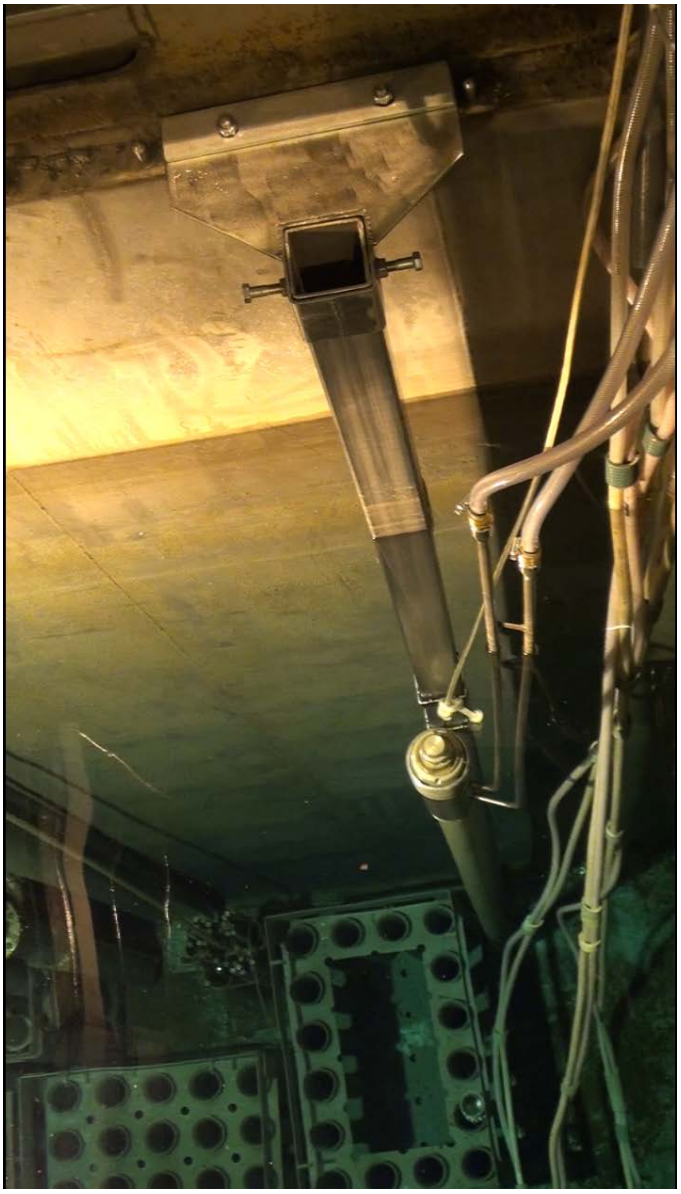

Figure 4 Top view of measuring stand with channel with spent fuel element inserted.

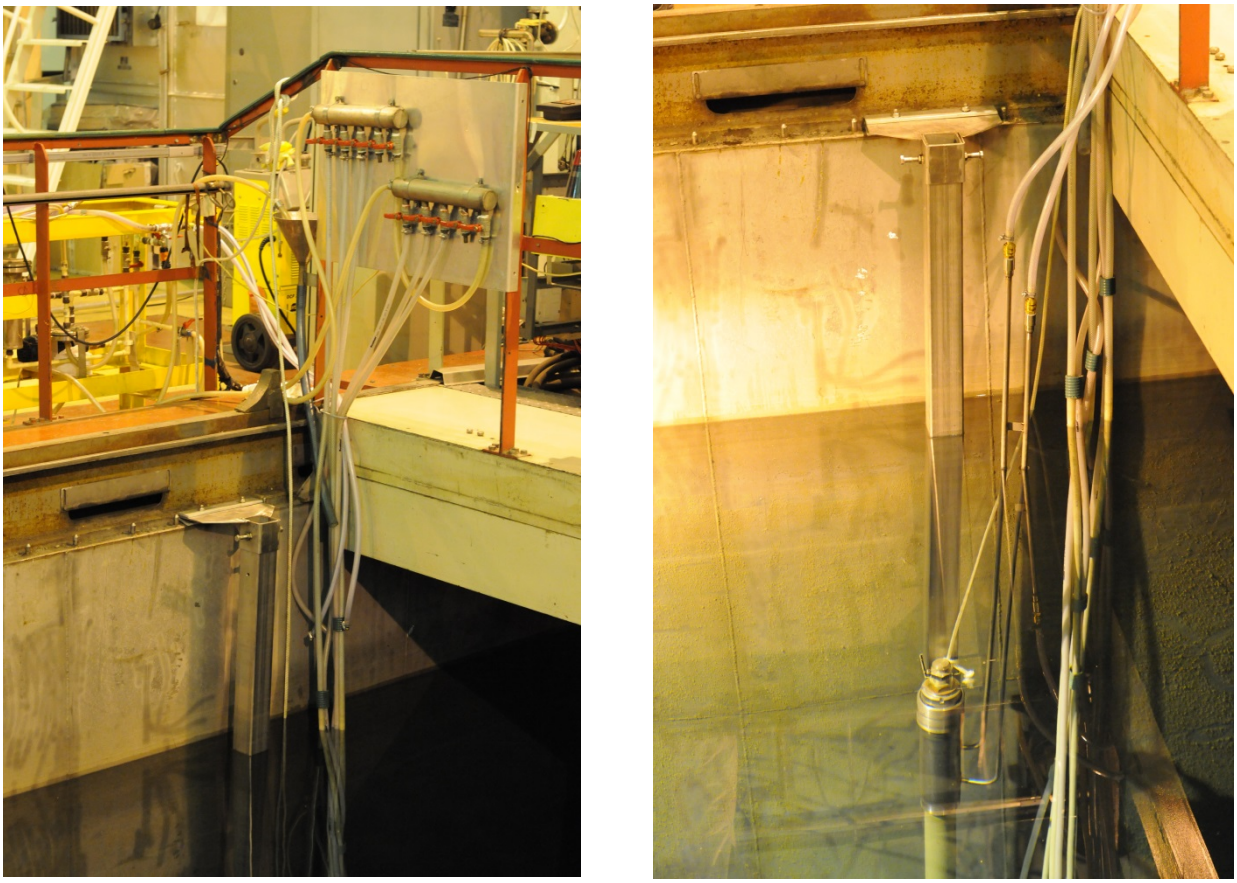

Figure 5 Side view of measuring stand with channel with spent fuel element inserted.

4. Results of sipping tests

Results of sipping tests mentioned earlier in the text are collected in following tables. They are divided into two groups – one group represent sipping test of LTA's done right after unloading from reactor and after three years of cooling. The other group are the results of sipping test of both LTA's and actual fuel elements, done using special measuring stand. Second group are the first results of measurements conducted in scope of full scale measurement program started after alarming results from MC002 measuring. Preliminary measurement mentioned in table 2 is simply a measurement right after insertion into stand so it can be treated as background activity measurement

Table 2 Sipping test results of MC LTA MC001 and MC002

Fuel element	Date of measurement	FP activity [Bq]		
		Cs–137	Eu–154	Eu–155
MC001	**16.05.2011**	**575**	**750**	–
	05.07.2014	**300**	–	–
	02.10.2014	**2150**	–	–

MC002	**16.05.2011**	**215**	**–**	**–**
	05.07.2014	**21050**	**–**	**–**
	02.10.2014	**41550**	**–**	**–**

Table 3 Sipping test results of MC type LEU elements obtained using new measuring stand.

Element No.	Date of measurement	Measurement type	Gamma spectrometric measurement [Bq/l]	
			Cs–134	Cs-137
MC001	25.06.2015	**Preliminary**	**—**	**77**
	26.06.2015	**After 24 h**	**950**	**6900**
MC002	25.06.2015	**Preliminary**	**—**	**55**
	26.06.2015	**After 24 h**	**14000**	**110000**
MC003	01.06.2015	**Preliminary**	**410**	**530**
	02.06.2015	**After 24 h**	**12000**	**16000**
MC012	09.06.2015	**Preliminary**	**240**	**310**
	10.06.2015	**After 24 h**	**250**	**260**

Measurement error: 15 – 18%

5. Conclusions

Sipping test results of MC002 LTA and MC003 fuel element indicates some fuel issues appearing after irradiation in core. Cause of such high levels of FP activity is still unknown and is still being investigated. After consultations with Argonne National Laboratory, US Department of Energy and Areva CERCA possible solution is to send susceptible elements to France or Belgium for dismantling and further investigation of leakage cause.

6. References

[1] Collective work edited by K.Pytel, "Operational Safety Analysis Report of Maria Reactor", Świerk, March 2015.

[2] Annex 2012/1 to "Operational Safety Analysis Report of Maria Reactor", "MARIA reactor core conversion to MC type fuel", July 2012.

[3] M. Migdal, "Brief history of MARIA conversion from HEU to LEU", RETRT 2014 – 35th International Meeting on Reduced Enrichment for Research and Test Reactors, October 12-16, 2014, Vienna, Austria.