Advanced fuel in the Budapest Research Reactor

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Extended Abstract

Introduction

The Budapest Research Reactor [1], the first nuclear facility of Hungary started to operate in 1959. The main goal of the reactor is to serve neutron research, but applications as neutron radiography, radioisotope production, pressure vessel surveillance test, etc. are important as well. The neutron research will get a much improved tool, when the cold neutron source will be put into operation. The Budapest Research Reactor is a tank type reactor, moderated and cooled by light water. The reactor core is in a cylindrical reactor tank, made of a special aluminium alloy. The diameter of the tank is 2300 mm, the height is 5685 mm. The heavy concrete reactor block is situated in a rectangular semi-hermetically sealed reactor hall. The area of the reactor hall is approximately 600 m^2. It is ventilated individually.

After a reconstruction and upgrading in 1967 the VVR-SM type fuel elements were used in it. These fuel elements provided a thermal power of 5MW in the period 1967-1986 and 10 MW after the reconstruction [2] from 1992.

In the late eighties the Russian vendor changed the fuel elements slightly, i.e. the main parameters of the fuel remained unchanged, however a higher uranium content was reached. This new fuel is called VVR-M2. The geometry of VVR-SM and VVR-M2 are identical, allowing the user to load old and new fuel assemblies together to the active core. The first new type fuel assemblies were loaded to the Budapest Research Reactor in 1996.

The present paper describes the operational experience with the new type of fuel elements in Hungary.

Old and new fuel

As it was said above, the VVR-SM and VVR-M2 fuel elements are rather similar to each other. However some basic parameters of the two types differ. These differences are specified in Table 1.

Table 1. ***Fuel specification***

Data	Old (VVR-SM)	New (VVR-M2)
Cladding thickness [mm]	0.9	0.75
Thickness of fuel [mm]	2.5	2.5
Fissile material composition	Al-UAl_4 eutectic, in Al matrix	UO_2 - Al mixture
Thickness of fissile material in the fuel ("meat" thickness) [mm]	0.7	1.0
Number of fuel elements in the assembly	3	3
^{235}U concentration in the active core [g/assembly-litre]	61.2	69.2
^{235}U concentration in the fissile material [g/cm]	0.5	0.57
Pressure drop in initial core [bar]	0.33	0.33
Average ^{235}U content of fuel assembly [g]	38.9	44.0
Maximal clad temperature [°C]	104	104
Volumetric water content of the elementary cell [%]	54.2	54.2
H/U in elementary cell	235	208
k_∞	1.637*	1.654*
Maximal allowed burn-up [%]	60	60

* according to recent (unpublished) calculations

The geometry of the two assemblies (old and new) are identical, i.e the elementary cell, the outer diameter, the active length, the assembly heads are identical. Consequently there is no difference in the cooling surfaces of the assemblies. The cladding material is in both cases Al of reactor purity (SZAV-1), the fuel enrichment is 36% ^{235}U for both fuel element types. The data identic for both fuel element types are not given in Table 1.

As it can be seen from Table 1, the difference between the two fuel types is slight, but however mainly due to the reduction of the cladding thickness the fissile material content of the fuel assemblies is significantly higher in the new fuel, than it was in the old one.

The licensing of the new fuel elements required reactor physics calculations for normal operation and for accident conditions as well. The input data for these calculations are the number densities, given in Table 2.

Table 2. ***Number densities for the elementary cell***

Type	Isotope	Number density $[10^{24}/cm^3]$	
		Old	New
"Meat"	^{235}U	1.2912×10^{-3}	0.94058×10^{-3}
	^{238}U	2.2955×10^{-3}	1.64457×10^{-3}
	^{16}O	-	5.17030×10^{-3}
	^{27}Al	4.8430×10^{-2}	4.91997×10^{-2}
Clad	^{27}Al	6.0226×10^{-2}	6.02260×10^{-2}

Analysis of accidents

All possible accidents were analyzed during the reconstruction period, before the new start-up procedure began in 1992. These analyses, described in the Safety Analysis Report of the reactor, served as a basis for the licensing. The analyses were performed for the VVR-SM fuel, but the results of these analyses are valid for the VVR-M2 fuel as well. Only the following assumptions had to be considered.

As a basic point of the safe operation of the research reactor is the protection of the fuel cladding. To protect the cladding, the boiling of the coolant is not allowed, because boiling could lead to the formation of bubbles. The permanent presence of bubbles could cause cavitation type corrosion in the cladding material.

Based on the data in the literature and on the results of our own research, boiling on fuel surface can be avoided, if the cladding temperature does not reach 114 °C. This conservative value for a given power and for given coolant conditions is determined by two parameters. These two parameters are the allowed maximum of the power non-uniformity factor and the heat transfer value. These values obviously do not depend on the material properties, neither of the fuel nor of the cladding.

Operation

The operation of the research reactor has to fulfil the various demands by research and other applications. The reactor was operated according to the pre-determined timetable throughout its operation period. These timetables have always been revised and modified according to the changes in the demand. The timetable was last modified for the year 1995. There were reactor operation periods of 112, 270 and 450 hours of continuous operation and one cycle consists of 900 MWdays. It means, that one cycle was about 90 effective days, which was followed by a refuelling period of two weeks. The 1995 timetable was planned for 4476 operational hours for the year and this amount was exactly fulfilled. The total energy production was 1883 MW days. The reliability of the reactor was very good as in the 1995 operation period only two unexpected shut downs occurred. The timetable for 1996 has the same structure as that for 1995, the operation period will be somewhat shorter, i.e 3894 hours are planned.

Operational experience with the new fuel

Operational experience in the Budapest Research Reactor is generally excellent, e.g. no fuel failure has been detected since the last reconstruction (1992). The average burn-up levels (55%) reached in the Budapest Research Reactor are relatively high in comparison to burn-up levels reached in similar reactors.

There were only two cladding failures from 1967 up till the last reconstruction. These two failures were slight leakages, they happened both at the beginning of a fuel cycle. This indicates, that the failures were caused by production failures, and are not related to operation.

The first group of VVR-M2 (new) fuel elements (38 of the entire 229) were loaded in January 1966 into the core. The second group of VVR-M2 fuel elements consists of 46 elements, so there are now altogether 84 new elements in the core. The reactivity coefficient measurements in both cases resulted in the same values as in start-up measurements for cores loaded with VVR-SM (old) elements. Two differences have been detected anyhow. The first one is in the power distribution due to the increased fuel amount, the second one is the increase of the cladding temperature, due to the decreased cladding thickness. The measured cladding temperatures were about 98 °C, the warning level is set to 104 °C (see Table 1.).

Conclusion

Experience (almost one year) has proved, that new (VVR-M2) and old (VVR-SM) type of fuel can be used together, without any problem.

References

1 I. Vidovszky: Research Reactor in Budapest, ENS Regional Meeting: *Nuclear Energy in Central Europe: Present and Perspectives*, June 13 - 16, 1993, Portorož, Slovenia, Proceedings p2

2 T. Hargitai: Dismantling and Reconstruction of the Budapest Research Reactor, *IAEA Topical Seminar on Management of Ageing of Research Reactors*, Geesthacht, Germany, May 1995