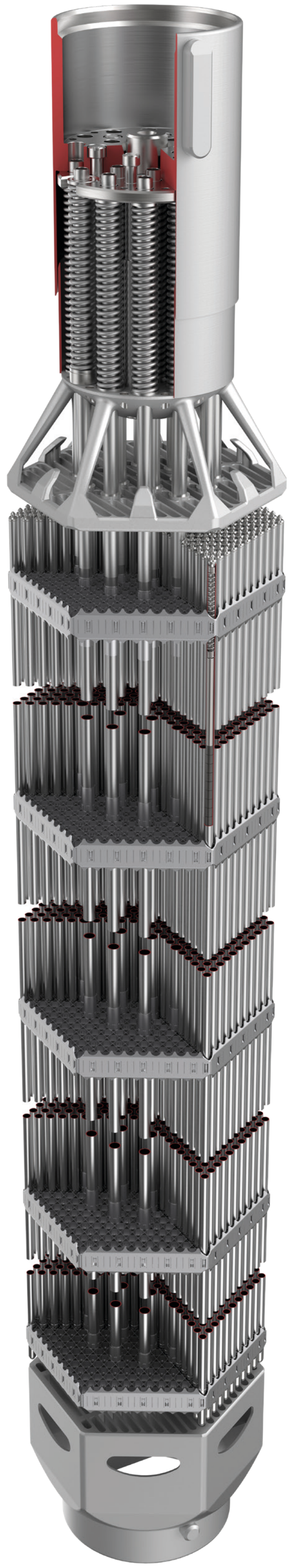
Westinghouse

VVER-1000 Fuel Products



Background

The Robust Westinghouse Fuel Assembly (RWFA) design has rapidly become the Westinghouse standard fuel product for the VVER-1000 units in Ukraine. The RWFA design is an evolution of Westinghouse´s previous VVER-1000 fuel design, WFA, which was first introduced as Lead Test Assemblies in South Ukraine Unit 3 in 2005.

Mechanical features and stronger materials were introduced in RWFA to avoid damage from mechanical interference during the core loading and unloading. The RWFA product has demonstrated excellent performance and reliability. Moreover, it is designed for the conditions following planned power uprates as well as load follow operation.

Westinghouse is also introducing a modified RFWA design for the Temelín nuclear power plant in the Czech Republic. The new design, which will be demonstrated in a Lead Test Assembly (LTA) program, will include fewer spacer grids for the assembly to be compatible with non-Westinghouse fuel, and material upgrades to further benefit the fuel economy and performance.

Description and benefits

The VVER-1000 RWFA design is shown in the illustration to the right, some key features are:

- **Bottom Nozzle** – includes a taper on the bottom of all six faces and increased edge breaks, which will minimize the mechanical interaction during the core loading.
- **Top Nozzle** – this is removable to enable fuel rod repair and equipped with deflectors to ease the core loading.
- **Grids** – the mechanical strength has been increased through use of Inconel 718 for all 16 grids, inner straps in all directions and more robust outer straps.
- **Fuel Rods** – totally 312 with ZIRLO® cladding tubes. Long, solid bottom end plugs for debris fretting protection.
- **Skeleton** – thimble tubes and instrumentation tube in ZIRLO®, these are double-bulged to the sleeves of the grids (see photo on the next page) resulting in a very robust structure.

Key data for the RWFA design and the Temelín LTA design are listed in the next section.

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Technical Data

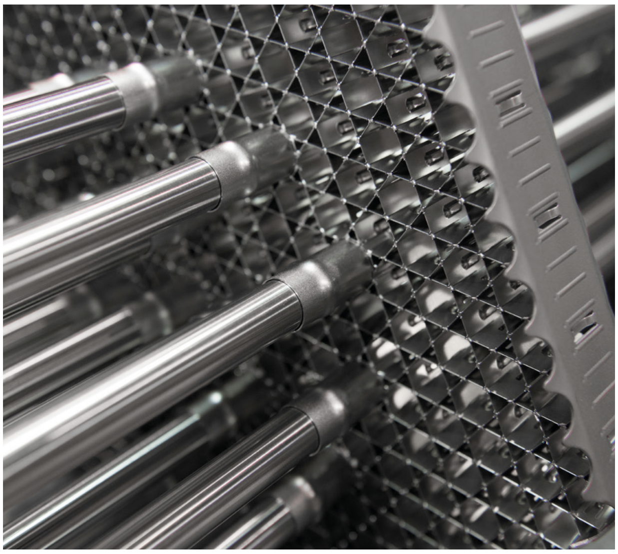
Parameter	RWFA	Temelín LTA	Unit
Fuel mass (in fuel rod/fuel assembly)	1.77/550.8	1.83/569.6	kg UO_2
Active stack length	3530	3650	mm
Blanket length (lower/upper)	152.4/152.4	120/150	mm
Base of fuel stack in relation to Rb-plane	228.4	203.5	mm
Fuel assembly width / length (from Rb-plane)	234/4520	234/4520	mm
Rod inner/outer diameter	8.001/9.144	8.001/9.144	mm
Pellet diameter	7.844	7.844	mm
Rod material type	ZIRLO®	Opt ZIRLO™	
Fuel assembly material types of main parts	Stainless Steel/ZIRLO®	Stainless Steel/ZIRLO®	
Number of fuel rods per fuel assembly	312	312	
Number of instrument tubes	1	1	
Number of guide tubes	18	18	
Fuel rod pitch	12.75	12.75	mm
Number of grids (all types) per fuel assembly	16	13	
Fuel rod length	3898.1	3908	mm
Fuel rod internal pressure	2	2	MPa
Fuel rod inner gas composition	He	He	

– The LTAs are designed to meet the bypass flow criteria defined by CEZ.

Experience

As of 2018, the Westinghouse RWFA product has been delivered to six different VVER-1000 units in Ukraine, with a total number of delivered fuel assemblies (including WFA) exceeding 1000 by the end of the year. The inspections and Post Irradiation Examinations (PIEs) of the fuel show excellent performance of both the WFA and the RWFA designs. The fuel assembly distortion has been very limited, with less than 10 mm bow and twist, and the Temelín LTAs are expected to perform within this range as well.

With the mechanical changes introduced in RWFA no damages during core loading or unloading have been recorded.



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Component materials and weight datasheet

RWFA design

Component	Material	Total Weight (kg)	Total Volume (m^3)
Bottom nozzle	Stainless steel 304L	14.427	1.83E-03
Guide thimble & Instrument tube assemblies	ZIRLO®	14.699	2.24E-03
Top grid assembly (16)	Inconel A718	0.800	9.73E-05
Middle grid assembly (2-15)	Inconel A718	11.200	1.36E-03
Bottom grid assembly (1)	Inconel A718	0.850	1.03E-04
Top nozzle	Stainless steel 304L	22.814	2.92E-03
	Inconel A718	3.606	4.39E-04
Fuel tube	ZIRLO®	120.526	1.83E-02
Bottom end plug	Zircaloy-4	9.360	1.44E-03
Internal fuel rod spring	Stainless steel 302	3.245	4.06E-04
Top end plug	Zircaloy-4	0.874	1.25E-04
Spacer, fuel rod	Stainless steel 304L	8.237	1.06E-03
Pellet stack	UO_2	550.9	N/A

Temelín Lead Test Assembly design

Component	Material	Total Weight (kg)	Total Volume (m^3)
Bottom nozzle	Stainless steel 304L	14.863	1.88E-03
Guide thimble & Instrument tube assemblies	ZIRLO®	14.686	2.24E-03
Top grid assembly (13)	Inconel A718	0.800	9.73E-05
Mid grid assembly (7-11)	Zr- 1% Nb	3.433	5.23E-04
Mid grid assembly (3-6, 12)	Zr- 1% Nb	3.338	5.08E-04
Mid grid assembly (2)	Inconel A718	0.800	9.73E-05
Bottom grid assembly (1)	Inconel A718	0.850	1.03E-04
Top nozzle	Stainless steel 304L	23.095	2.92E-03
	Inconel A718	3.606	4.39E-04
Fuel tube	Opt. ZIRLO	121.462	1.85E-02
Bottom end plug	Zircaloy-4	6.708	1.03E-03
Internal fuel rod spring	Stainless steel 302	3.245	4.06E-04
Top end plug	Zircaloy-4	0.874	1.32E-04
Pellet stack	UO_2	569.6184	N/A

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Temelín Lead Test Assembly design

Additional Technical Data

Pressure loss coefficients vs components elevation

	Elevation* (mm)	Height (mm)	Pressure loss coefficient**
Bottom nozzle	0	142,5	0.26
Fuel rod bottom end plug elevation	150	Not applicable	Not applicable
Bottom grid	175	20	0.63
Non-mixing vane mid grid	458.5	20	0.61
Non-mixing vane mid grid	798.5	20	0.61
Non-mixing vane mid grid	1138.5	20	0.61
Non-mixing vane mid grid	1478.5	20	0.61
Non-mixing vane mid grid	1818.5	20	0.61
Mixing vane mid grid	2158.5	20	0.86
Mixing vane mid grid	2498.5	20	0.86
Mixing vane mid grid	2838.5	20	0.86
Mixing vane mid grid	3178.5	20	0.86
Mixing vane mid grid	3518.5	20	0.86
Non-mixing vane mid grid	3773.5	20	0.61
Non-mixing vane top grid	3983	20	0.61
Top nozzle	4079,5	440,5	0.68
Rod bundle friction	Not applicable		4.87
Fuel assembly total			**15.06**

* Elevation constitutes distance from Rb plane to bottom of the component.
** Reference coolant area is 0.025380 m^2. Reference Reynold's number is 500 000.

Fuel assembly lateral stiffness

The minimum lateral stiffness of the Temelin LTA fuel assembly for a 25.4 mm displacement is 48.9 N/mm (BOL) and 26.6 N/mm (EOL) at room temperature in air.

BOL and EOL dynamic grid stiffness and strength

The table below provides grid dynamic strength and stiffness at BOL at elevated temperature in air. EOL grid stiffness and strength are bounded by the BOL values.

Stiffness	4712 kN/m
Dynamic Crush Strength	7139 N

Top nozzle as-built spring characteristics and fuel assembly growth

The table below presents top nozzle holddown force and stiffness at BOL Hot Full Power conditions. The fuel assembly growth is 5 mm at 60 MWd/kgU.

Top nozzle hold down force (nominal)	7402 N
Top Nozzle hold down spring stiffness (nominal)	195 N/mm

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