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Ukrainian Experience in Diversification of Nuclear Fuel Supplies in line with the European Energy Security Strategy

STATE SCIENTIFIC AND TECHNICAL CENTER FOR NUCLEAR AND RADIATION SAFETY
SSTC NRS

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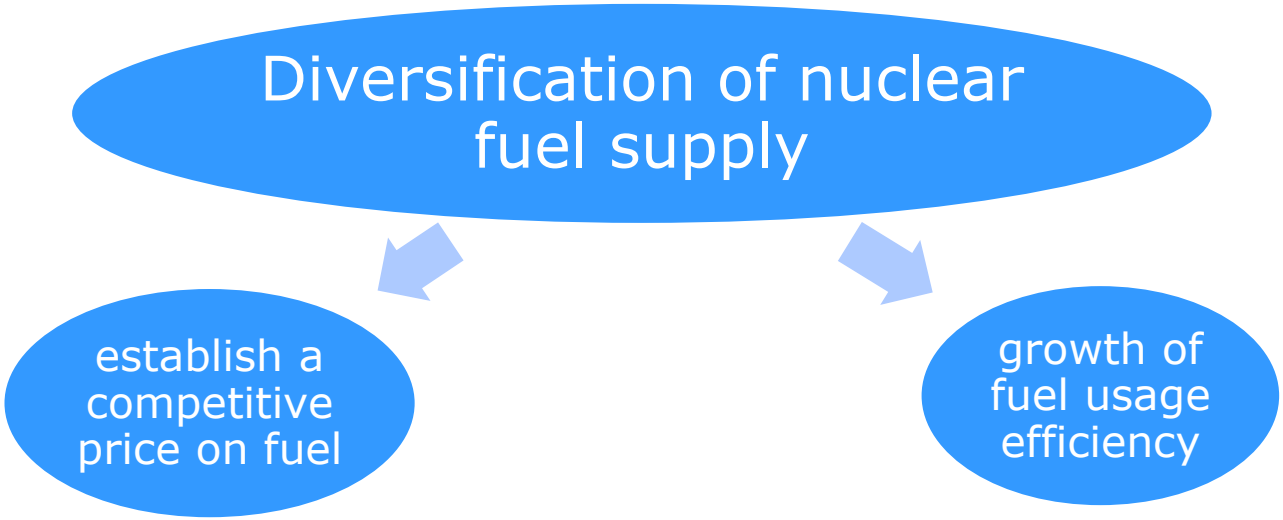
Qualification of Westinghouse Fuel Assemblies for Ukrainian NPPs



"…an overall diversified portfolio of fuel supply is needed for all plant operators…"

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL
European Energy Security Strategy

Qualification of Westinghouse Fuel Assemblies for Ukrainian NPPs

Ukraine Nuclear Fuel Qualification Project

6 LTA

- the justification of compatibility of Russian and Westinghouse design FAs
- LTAs were licensed and Ukrainian Regulator Authority permission on their trial operation was received
- six LTAs successfully worked out four fuel campaigns that were provided by the project at the SUNPP Unit №3 (17th-20th fuel campaigns from 2005 to 2010)

reload batch of 42 WFA

- reload batch of 42 Westinghouse FA was loaded for 21th fuel campaign of SUNPP unit №3
- Extension of Westinghouse FA trial operation at the SUNPP unit №2
- Extension of Westinghouse FA trial operation at the ZNPP unit №5

Qualification of Westinghouse Fuel Assemblies for Ukrainian NPPs

Westinghouse FA design improvement

Transfer of FA production from the plant in Columbia to plant in Vesteras	the increased rigidity of the frame by mounting of medium and upper spacer grids to guide channels
	use of gadolinium oxide (Gd_2O_3) as an integrated burnable absorber instead of zirconium diboride (ZrB_2) thin cover layer of fuel tablet
	use of zirconium alloy (Zr-1%Nb) for all middle spacer grids instead of alloy 718 because of low neutron capture cross-section and high corrosion resistance
Prevent the deformation of WFA spacer grids	spacer grids with changed outer plate profile and increased thickness were used
	Additional missed internal straps were added in the middle spacer grids
	spacer grids material changed from zirconium alloy on stainless
	top and bottom nozzles design were changed

Qualification of Westinghouse Fuel Assemblies for Ukrainian NPPs

Diversified FAs on Ukrainian NPPs now

SUNPP unit 3	SUNPP unit 2	ZNPP unit 5
• 3/4 core - RWFA • 1/4 core - TVSA	• 1/4 core - RWFA • 3/4 core - TVSA	• 2/4 core - RWFA • 2/4 core - TVSA

SNRIU approved the Technical Decision on trial operation of RWFA on ZNPP unit №1, 3, 4 and preliminarily SAR for RWFA

Safety and Licensing Aspects of Mixed Cores Operation

Specific Regulatory Requirements for New Nuclear Fuel Implementation

- Requirements for Nuclear Installation Modifications and Procedure of Their Safety Assessment (NP 306.2.106-2005).
- Approaches to Nuclear and Radiation Safety Regulation Under Implementation Projects of New Nuclear Fuel Modifications in Ukraine (SNRIU's Order №65 16.05.2002)

Safety and Licensing Aspects of Mixed Cores Operation

Approaches to Nuclear and Radiation Safety Regulation Under Implementation Projects of New Nuclear Fuel Modifications in Ukraine (SNRIU's Order №65)

Areas of new fuel safety justification	Operation of transient fuel loads with "mixed" core
	Fuel transportation and handling
	Fresh fuel storage
	Storage of spent fuel of all types in storage facilities at Ukrainian NPPs

Safety and Licensing Aspects of Mixed Cores Operation

“Mixed” Cores - Compatibility

The considered issues

- the simple geometric compatibility of differing fuel types
- thermal-hydraulic
- nuclear behavior
- thermal-mechanical design
- mechanical design

Safety and Licensing Aspects of Mixed Cores Operation

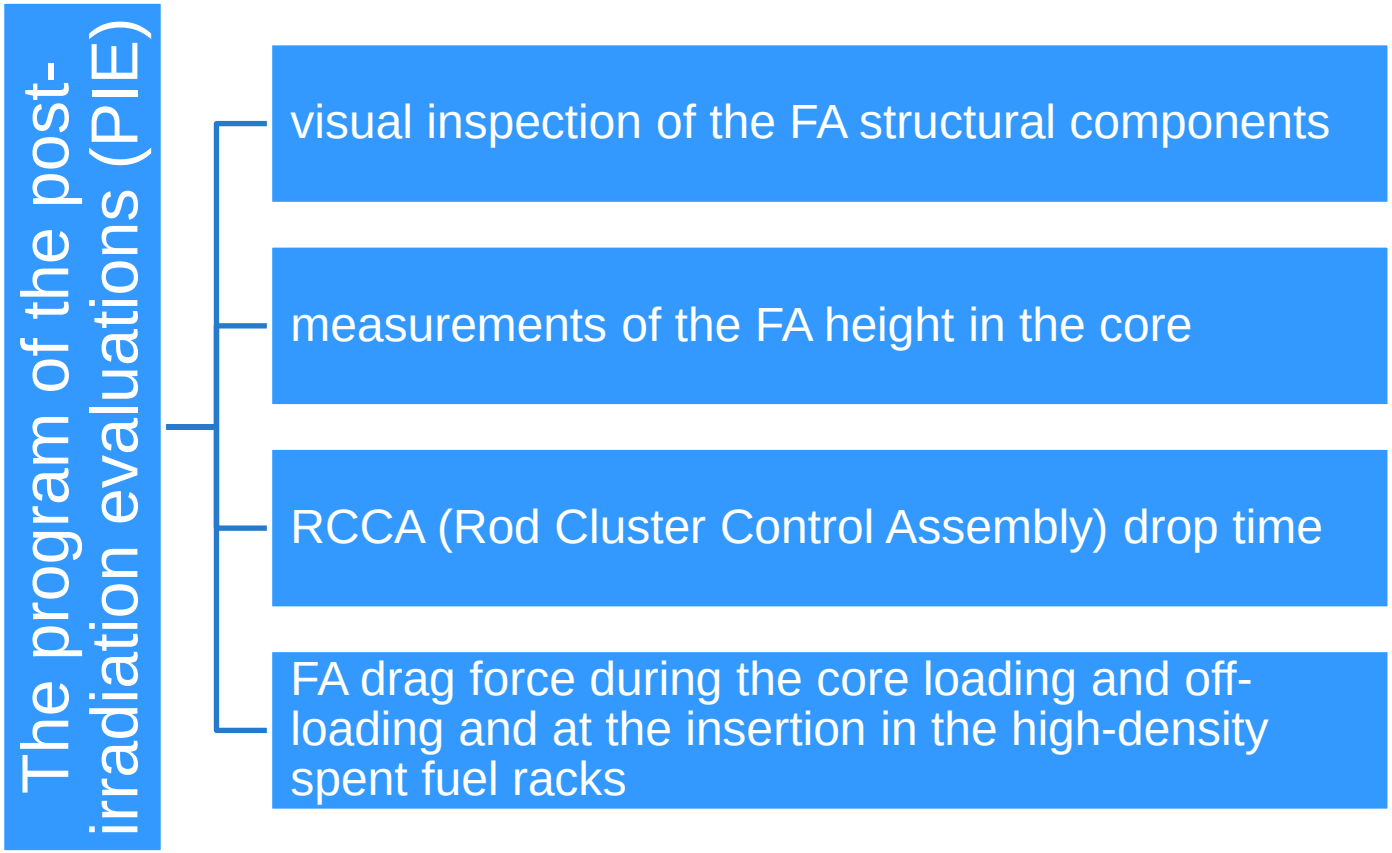
The core with WFAs is refueled in accordance with the current practice established at Ukraine's NPPs

The enrichment and profiling of WFAs for transition cores takes into account

- nuclear compatibility and interchangeability with the current FA inventory;
- meeting all design restrictions for all jointly operated fuel types;

the key nuclear parameters, used in the safety analysis for the equilibrium cycle with Russian design FA and WFA are very similar

Safety and Licensing Aspects of Mixed Cores Operation

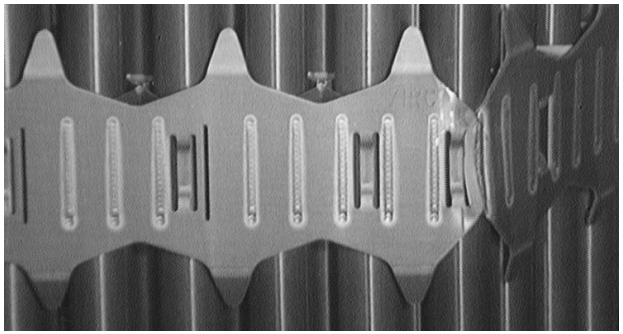


Safety and Licensing Aspects of Mixed Cores Operation

Additional measurements during the 2012 outage at SUNPP unit 3

- FA elongation
- FR growth and bow
- FA distortion

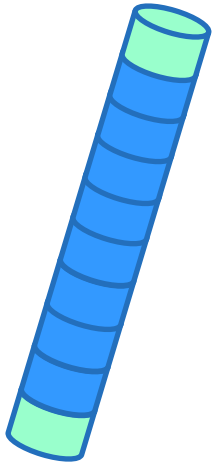
- the FA elongation, FR irradiation growth and bow, SG and FR cladding corrosion are within the design limits
- the assembly distortion (bow and twist) does not effect the RCCA drop time
- *deformation of the outer strap of some Mid-SGs can occur during loading of "fresh" WFA in the mixed core with the co-resident TVSA fuel*
  → design improvement



Safety and Licensing Aspects of Mixed Cores Operation

In-core monitoring system

Problem - the program for the power distribution reconstruction in reactor core was developed by the country that supplied nuclear fuel to Ukraine (Russia)



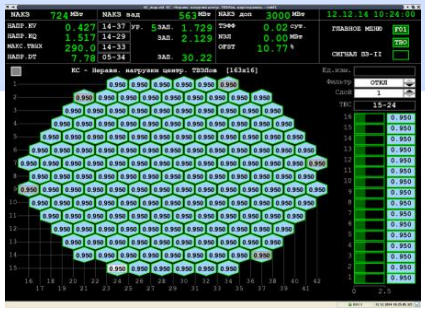
program was focused on the physical features of Russian design fuel (supplier did not realize an accounting of axial profiling of uranium-235 enrichment in fuel rod, etc.)

Safety and Licensing Aspects of Mixed Cores Operation

Two versions of the in-core monitoring systems (ICMS) were implemented and put into commercial operation at SUNPP

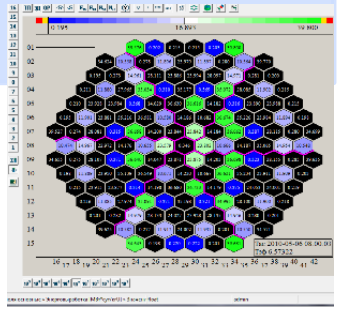
SUNPP unit 3

- the ICMS is used, where the Westinghaus program BEACON was used as the top-level software



SUNPP unit 2

- previously installed software "Voyage" is adapted to the control of reactor core with WFA
- few group cross section library prepared by Russian SVL program, (property of the Russian SNIIP-Atom company)



Safety and Licensing Aspects of Mixed Cores Operation

Two main ways of next step problem decision with the further extension of Westinghouse fuel assemblies on the units of the Zaporizhzhya NPP:

- replacement of the installed software "Voyage" with the physical calculation program BEACON → a case of dissemination of the experience of the SUNPP unit 3
- a new case in the form of the few group cross section library preparation in the format software "Voyage" for WFA and its verification without replacing the software and hardware of the ICMS

Safety and Licensing Aspects of Mixed Cores Operation

For today on Zaporizhzhya NPP unit 5

the ICMS software BEACON has been installed

but

the second option is also implementing by the operator

the first stage of the trial operation of ICMS with renewed few group cross section library was carried out during a 27th fuel campaign without a data outputting to operator for the reactor controlling and working parallely with BEACON software

Fuel transportation

MCC-5 - US fuel shipping package to transport the first Westinghouse assemblies through the territory of Ukraine

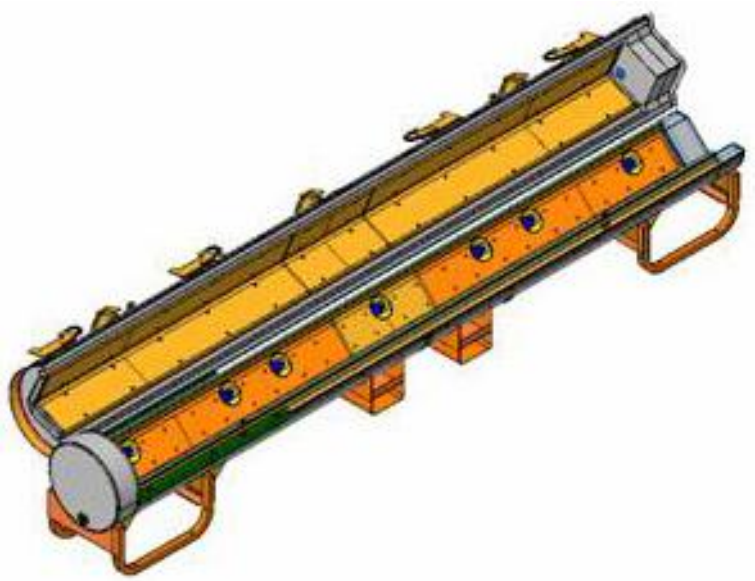
safety justification of the fuel transportation through the territory of Ukraine → a subject of a multifaceted technical review in the areas of safe handling of nuclear materials, nuclear and radiation safety, strength and reliability of structures

multilateral approval of the primary US certificate

Fuel Management

Traveler-VVER - new type of shipping package

- an individual fuel assembly confinement system
- a permanent neutron flux trap



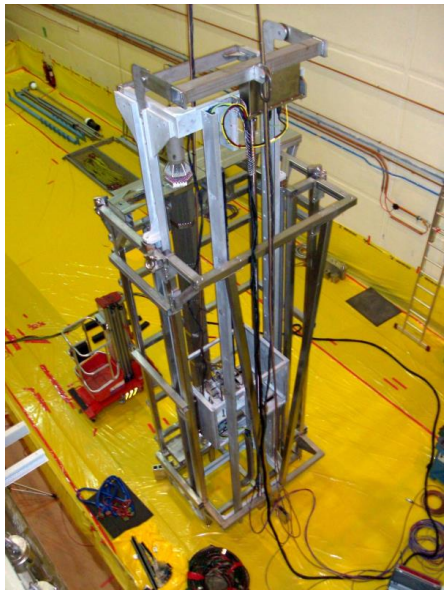
Criticality Safety Index

TK-C5	4.17
MCC-5	0.4
Traveller-VVER	0.7

Fuel Management

Fuel inspection/repair equipment

annual monitoring of the Westinghouse fuel assembly's condition during 4 fuel cycles → one of the conditions of the Regulatory Authority.



Westinghouse has designed and manufactured a fuel inspection and repair equipment (FIRE)

- study fuel assemblies and fuel rods
- obtain additional information on the fuel assemblies conditions during the period of refueling operation

Fuel Management

The utility's close-in objectives in FIRE usage:

- the adaptation of the FIRE to capability of the Russian design fuel assemblies control
- improvement of the equipment design for the removal of foreign objects from fuel assemblies
- conducting planned fuel inspections at NPP power units during the period of long overhauls without affecting the terms of the refueling operation

Fuel Management

Interim storages

Zaporizhzhya NPP

- on-site interim spent fuel storage facility
- the safe operation of the ISFSF with Westinghouse spent Westinghouse fuel assemblies was justificated

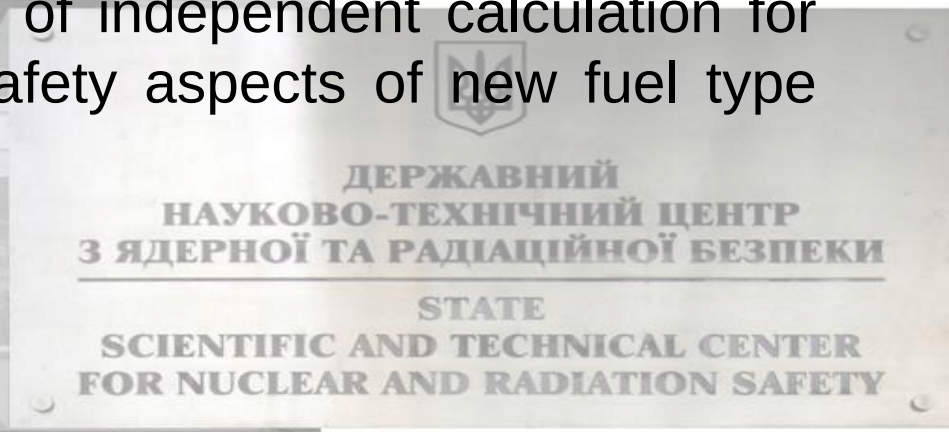
South Ukraine NPP

- use of Central Spent Fuel Storage Facility
- Safety analysis report that was developed in frame of facility licensing made provision for spent Westinghouse fuel assemblies storage

Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

State Scientific and Technical Center for Nuclear and Radiation Safety" (SSTC NRS) as a technical support organization of Ukrainian Regulatory Authority is involved in licensing process of new fuel type introducing at Ukrainian NPPs.

SSTC NRS policy of technical review of justification materials includes carrying out of independent calculation for as more as possible nuclear safety aspects of new fuel type introducing.



Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

Confirmation by independent assessments

↓

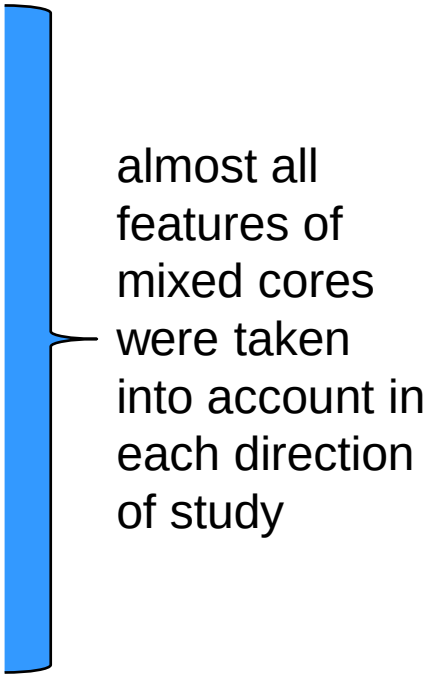
the wide range of safety aspects:

- neutron kinetic
- thermohydraulic
- operational safety
- radiation safety analysis aspects
- strength and design reliability issues etc.

Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

Established practice of licensing process of new fuel type introducing at Ukrainian NPPs supposes carrying out of next independent calculation:

- neutron-multiplying properties and few group cross-section library preparation;
- neutron kinetic characteristics and characteristics of transitional and stationary loading;
- thermohydraulic reliability of fuel pin in normal operation modes and in accidents;
- criticality of fuel storage and transportation systems;
- estimation thermo-mechanical behavior of fuel pin;
- estimation of new fuel type introducing effect on neutron fluence at reactor vessel.

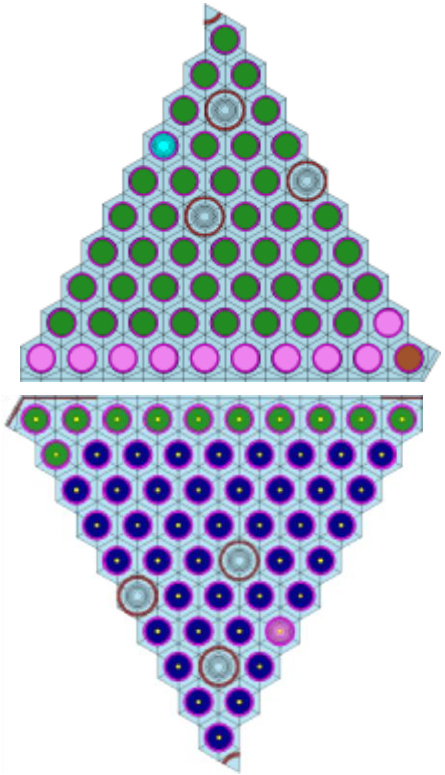


Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

Few group cross section library preparation

Taken into account features:

- fuel pellet geometry (absence/presence of central hole, outer diameter, etc.),
- constructional material and its geometry (spacer grid, guide tube, strengthen corner for TVSA type fuel assembly),
- radial profiling of fuel regard to enrichment,
- burnable absorber, type of burnable absorber applying (integrated or covered).
- effect of neighbored FA corners on pin power in peripheral row



Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

Core modelling – mixed core features

Neutron kinetic

- Irregular axial meshing of core model caused by axial profiling
- Differences in fuel pin geometry
- Burnable absorber features
- Different uranium mass for each type of fuel assembly

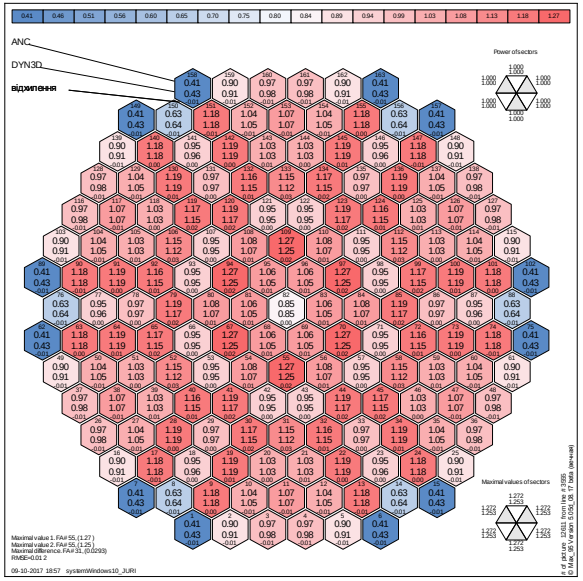
Thermohydraulic

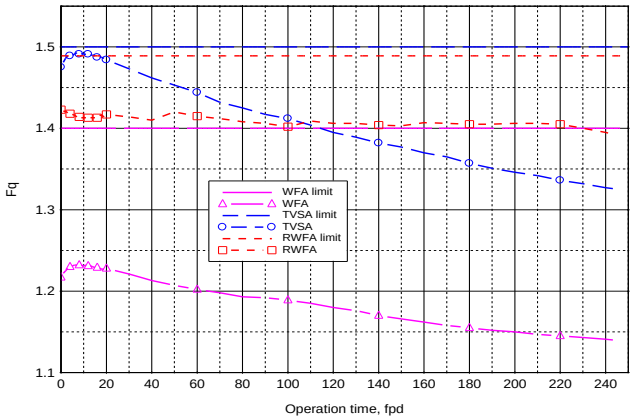
- Different loss coefficient of FA elements ($\Delta\zeta$ between WFA and TVSA amounts $\approx$36%)
- Different thermal physical properties (thermal capacity and conductivity) of pin materials

Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

Focus on compliance of next parameters:

- peaking factors, linear pin powers;
- assembly and pin averaged burnups;
- reactivity coefficients;
- working group CR and scram efficiency, etc.



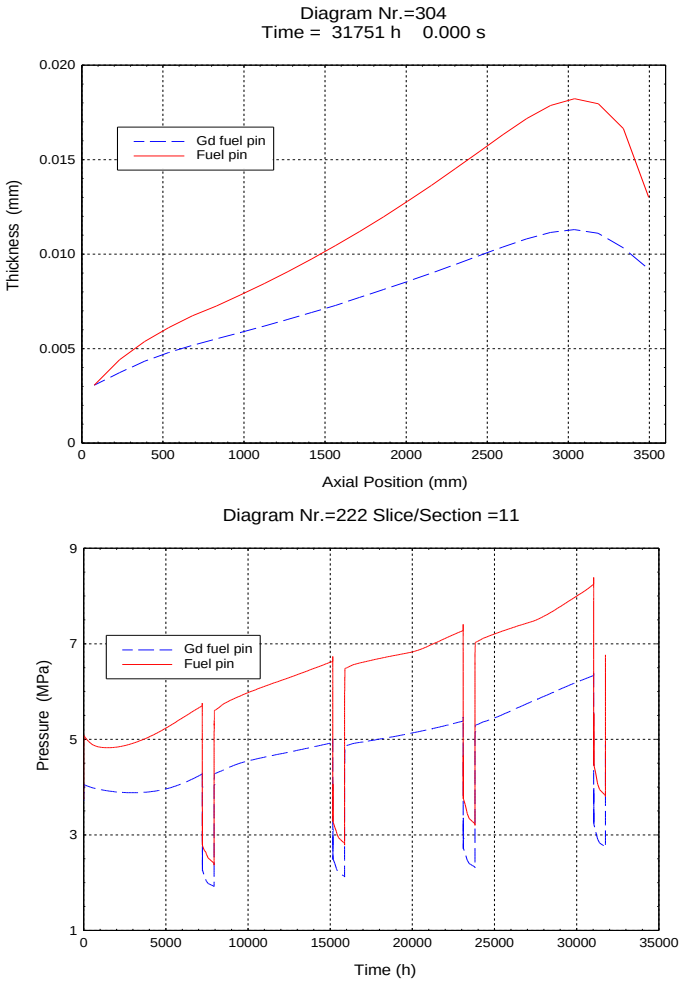


- some limits were established stricter than regulation (pin power peaking power)
- these factors are changed for each next fuel campaign as a function of number of the operated assemblies of each type in mixed core.

Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

Thermomechanical fuel behavior

- Both for normal operation modes and for accidents
- History of linear power change in each fuel pins for all transitional fuel loading was taken into account.
- Additional engineering factor Keng=1.2 to pin linear power was applied.
- Main attention was devoted to the pins with maximal value of linear power and with maximal value of burnup.



Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

Effect on vessel neutron fluence

Submitted justification materials of Westinghouse FA introducing - without direct assessment of this effect (only comparison of power distribution of peripheral FAs).

Confirmatory calculations were performed with use of full-scale model and accounting a pin-by-pin neutron sources

- 5÷7% decrease of growth rates of vessel neutron fluence.
- But taking into account fuel campaign duration under transition to RWFA fuel cycle the assessment of averaged for campaign vessel flux is more relevant in given case. Concerning the averaged for campaign vessel flux, its decrease in most loaded axial position amounts up to 3%

Ukrainian Regulatory Review Approach for Carrying out of Independent Confirmatory Calculation

Used SSTC NRS calculating models take into account most of aspects of new fuel type introduction and features of mixed cores

Carrying out of Independent Calculation

- significantly increases a quality assurance of technical review process as part of licensing procedure
- gives possibility to carry out a «quantitative» estimation of object parameters with use of own calculation results
- maintenance of qualification of the experts at a modern level in the field of estimations of safety of atomic energy objects
- Readiness of TSO to carry out of the analyses of various situations, incidents etc. by the order of a Regulatore body
- provides the Regulatory Authority with reasonable assurance that the justification materials are performed adequately

Conclusions

- A significant effort has been made to realize on this issue both from side fuel vendor, utility and Ukrainian regulatory authority with technical support organization. Today, Ukraine holds the leading position in diversifying nuclear fuel supply in Europe.
- It is planned to use nuclear fuel of alternetive supplier at six out of fifteen Ukraine's NPPs (South Ukraine NPP and Zaporizhzhya NPP). It fully complies with the European Energy Security Strategy and stating that overall diversified portfolio of fuel supply is needed for all plant operators.