Verification of computational models used in SEC NRS for independent evaluation of safety parameters during SNF transport

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INTRODUCTION

- SECNRS was established aiming to collect and apply new scientific knowledge for scientific and engineering support of nuclear and radiation safety regulation, including analysis and substantiation of criteria and requirements for nuclear and radiation safety
- One of the main types of works that correspond with the goals of the SECNRS establishment is the safety assessment of nuclear facilities and activities in the field of nuclear energy
- During safety assessment specialists of SECNRS often perform independent evaluation of safety parameters. This presentation focuses on computational models used in SECNRS for independent evaluation of safety parameters spent nuclear fuel (SNF) transportation and its verification

SAFETY REQUIREMENTS

- NP-053-04 “Safety regulations for transport of radioactive material”
- SSR-6 “Regulations for the Safe Transport of Radioactive Material”

SAFETY PARAMETERS	Normal conditions	Accident conditions
❖ Dose rate		
external surfaces of the package	2 mSv/h (10 mSv/h)*	-
external surfaces of the overpack	2 mSv/h	-
1 m from external surfaces of the package	-	10 mSv/h
2 m from external surfaces of the overpack	0.1 mSv/h	-
❖ K_{eff}	0.95	0.95
❖ Loss of radioactive contents	$10^{-6}A_2$ per hour	A_2 per week ($10A_2$ for ^{85}Kr)
❖ Temperature		
accessible surfaces of a package	50°C (85°C)*	-
ability to withstand thermal test	-	30 min in a 800°C fire

TUK-153 OVERVIEW

TUK-153

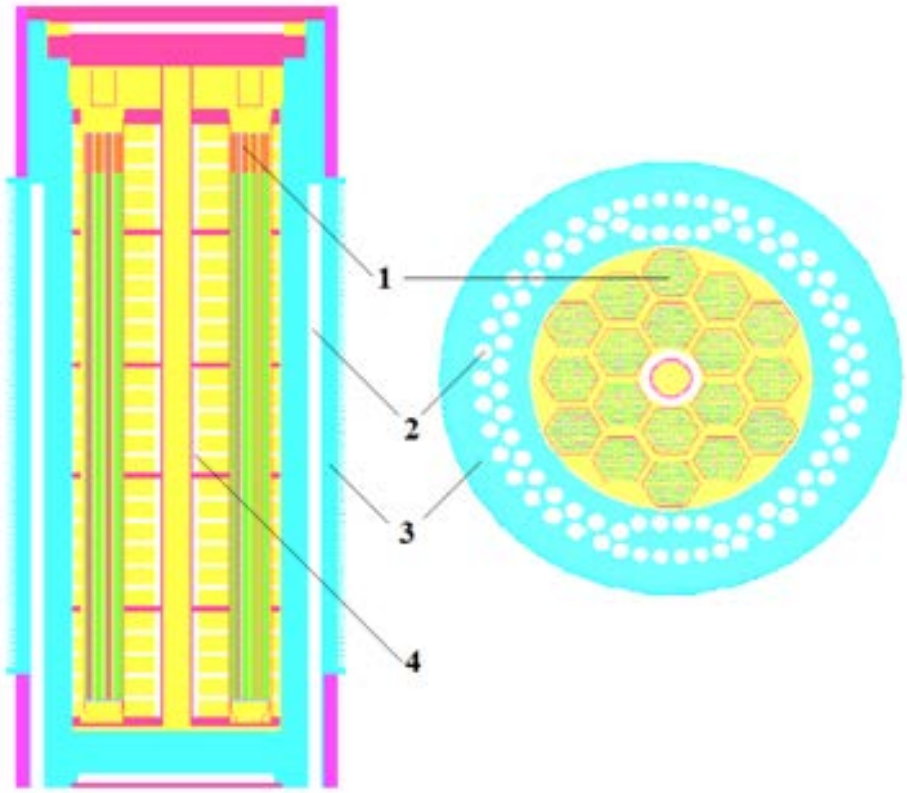
TUK-153 characteristics	
Constructor	**JSC «Energotex»**
Designer	**JSC «ECNC»**
Fuel	**WWER-1000**
Capacity	**18 SFA**
Burnup	**60 GWd/tU**
^{235}U initial enrichment	**4,925 %**
Weight of the loaded cask	**110 t**
Cask body	**ductile cast iron**
Neutron shielding	**polyethylene PE-HD**

TUK-141

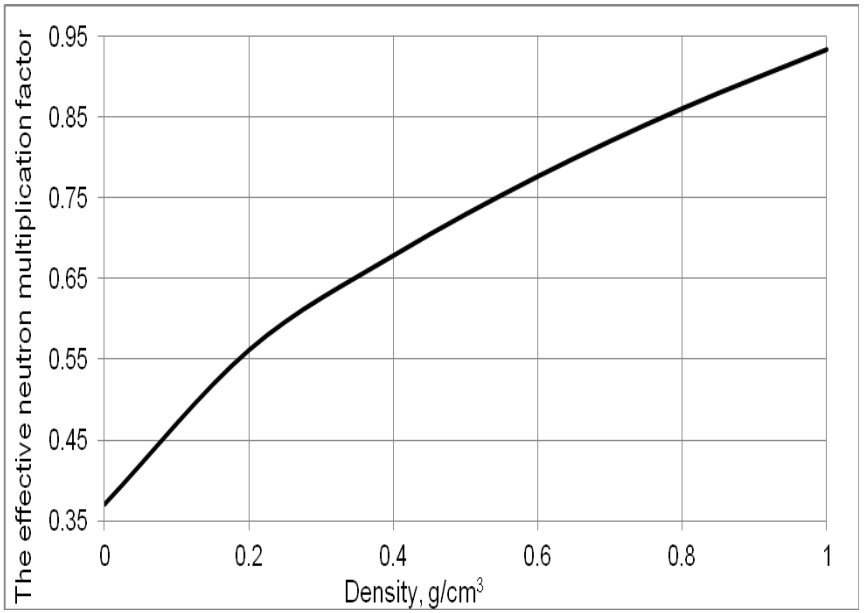
TUK-140

Study of nuclear safety parameters (1/2)

- All simplifications of the actual packaging design are conservative and lead to overestimation of the calculated K_{eff}



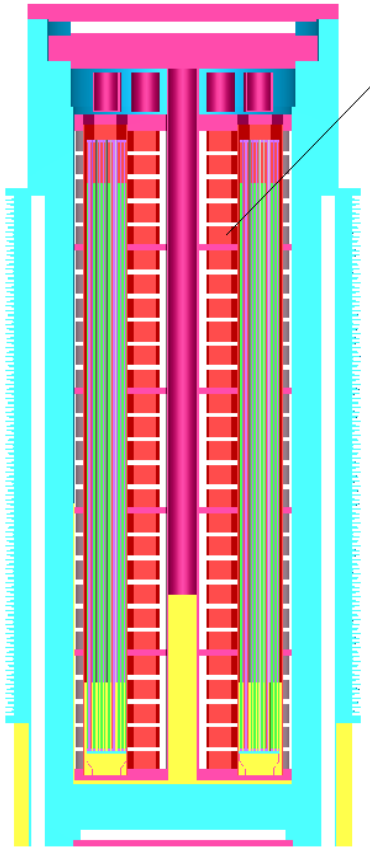
1 – SFA, 2 – high molecular weight polyethylene, 3 – ductile cast iron, 4 - basket

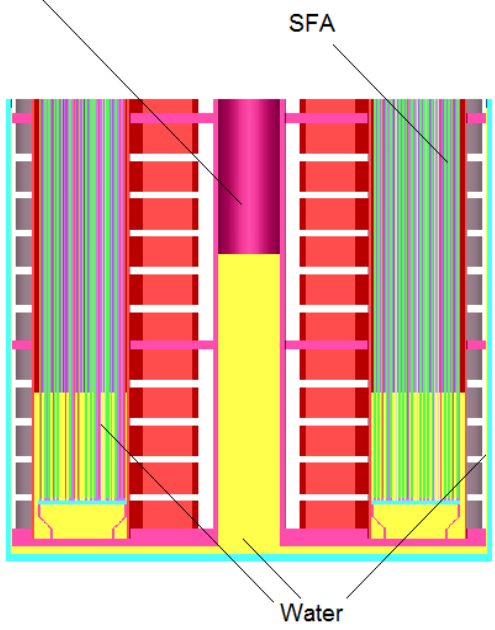


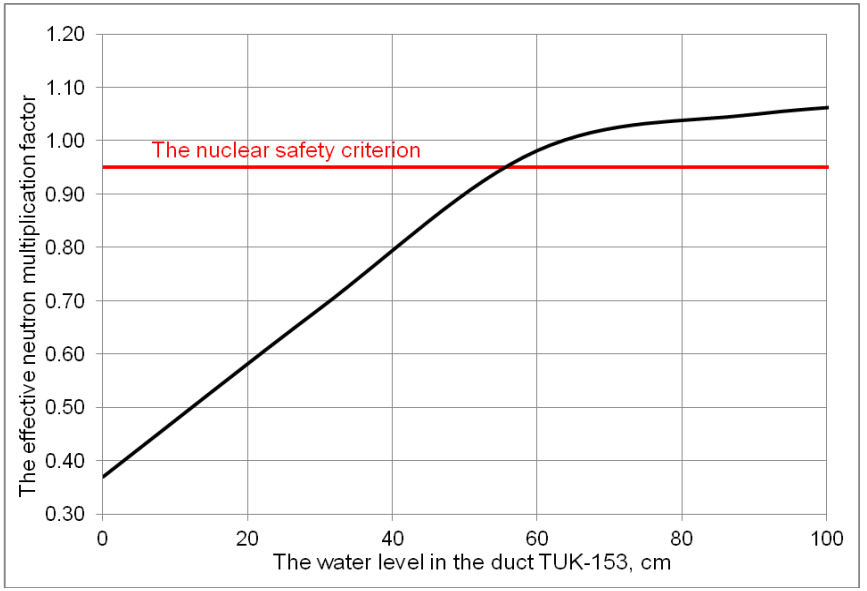
Nuclear safety is confirmed using very conservative "fresh fuel" approach, however…

Study of nuclear safety parameters (2/2)

- … the NP-053-04 require the need to consider not only the change of water density, but also the change of its distribution in the packing





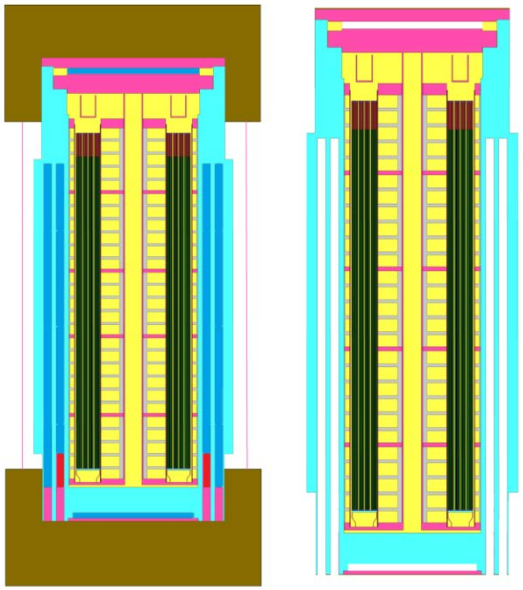


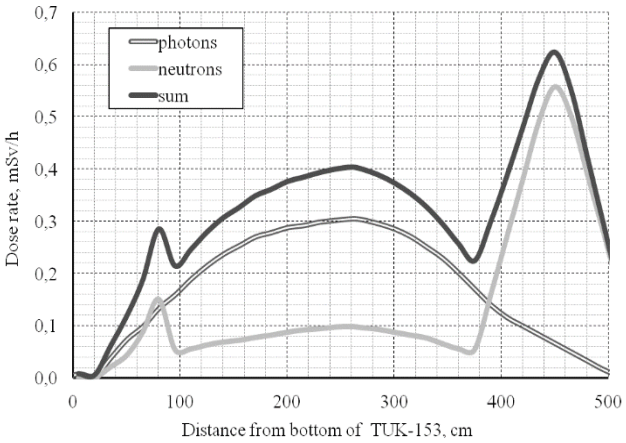
«Burn-up-credit» approaches:

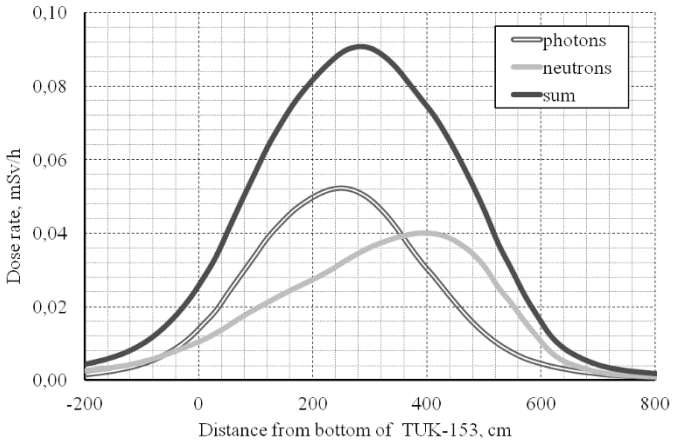
«actinides only»	at least 31 GWd/tU
«actinides + fission products»	at least 22 GWd/tU

Study of radiation safety parameters (1/3)

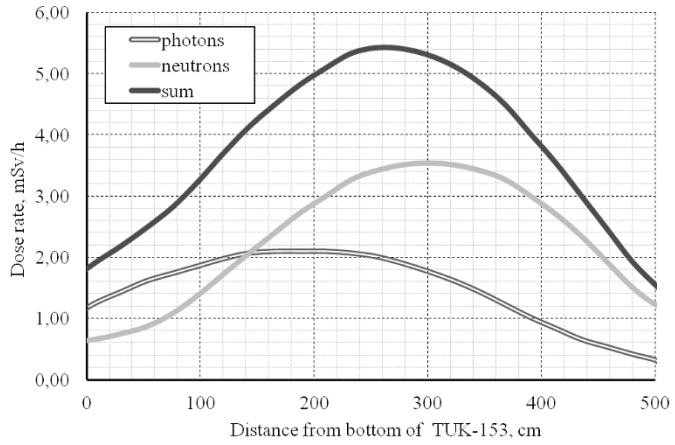
- all 18 SFA were identical and characterized by a maximum radiation source





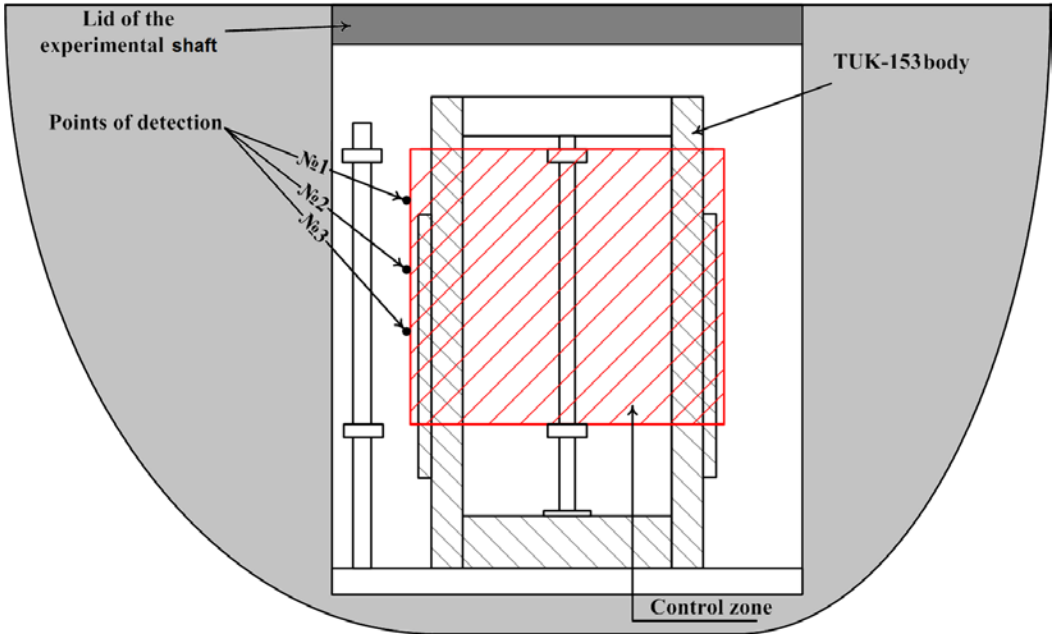


Area of detection	Operating conditions	Dose rate, mSv/h	
		Calculated values	NP-053-04
The surface of the TUK-153	Normal	0,625	2
2 meters from the surface of the vehicle		0,091	0,1
1 meter from the surface of the vehicle	Accident	5,4	10



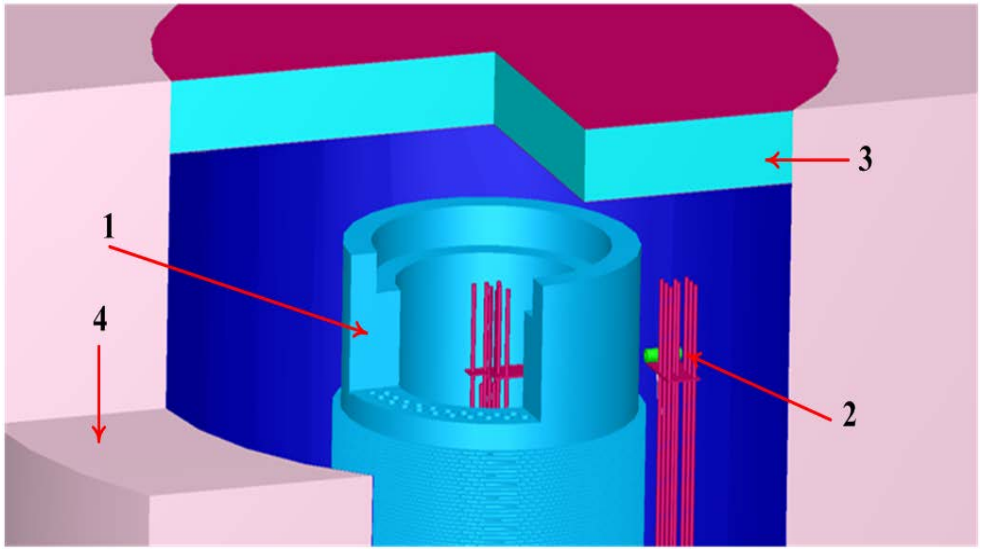
Study of radiation safety parameters (2/3)

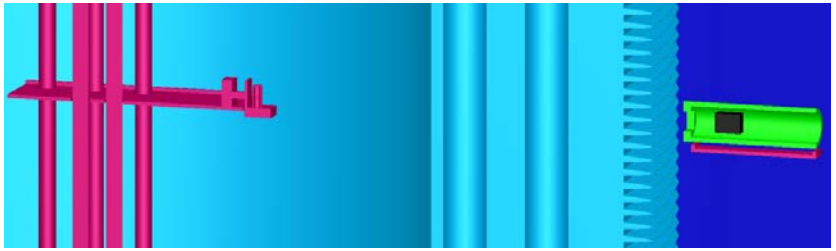
- ^{60}Co gamma-ray source
- CsI(Tl) scintillation detector



- detector № 1 is located near the chamfer for truck pins;
- detector № 2 is located near the chamfer for installation of TUK-153 to the vehicle;
- detector № 3 is located near the heat-removing ribs.

Study of radiation safety parameters (3/3)



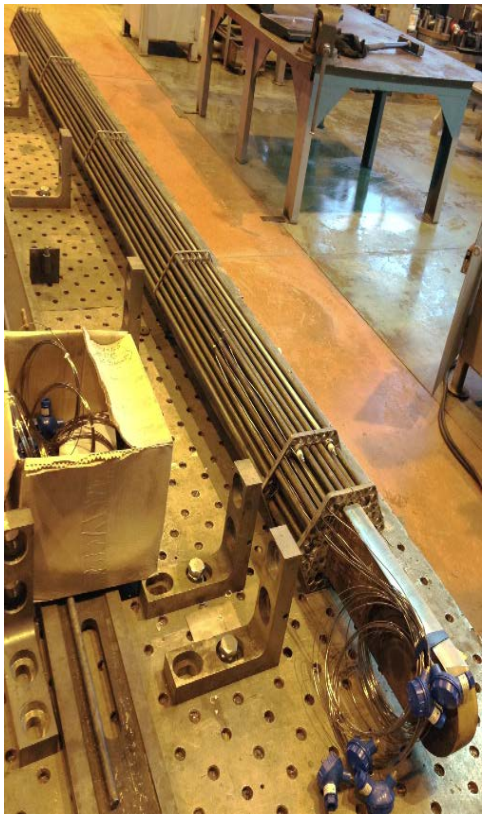


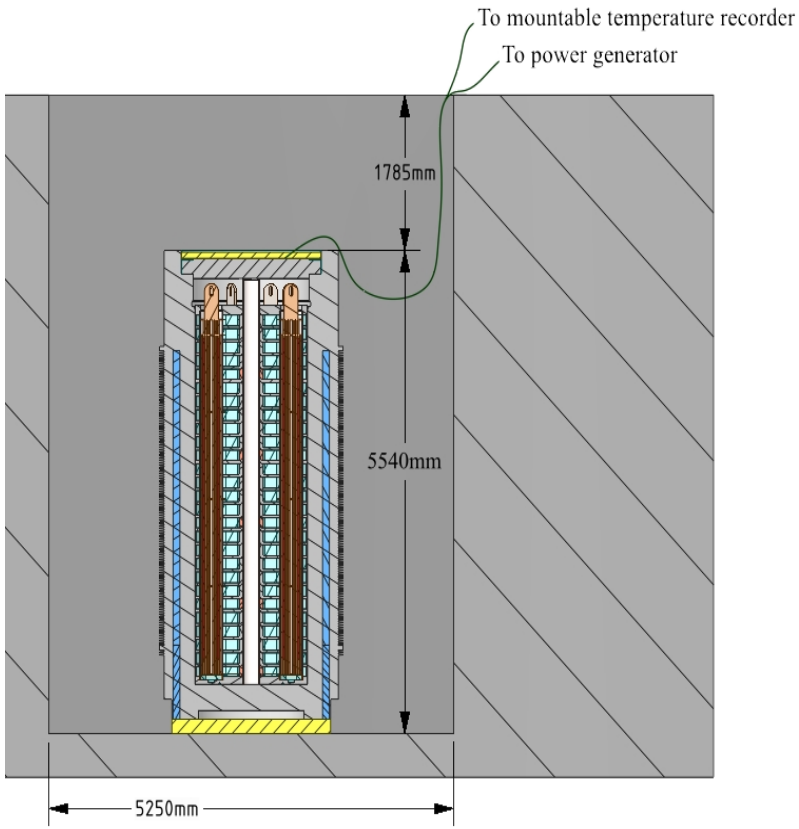
1 – TUK-153 body,
2 – stand of gamma control,
3 – lid of the shaft,
4 – gamma control shaft

Detector	№ 1	№ 2	№ 3
Average experimental value of dose rate, μGy/h	6,05	23,32	12,44
Calculated value of dose rate, μGy/h	6,71	27,45	13,91
Deviation, %	+10,9	+17,7	+11,8

Study of thermal characteristics (1/3)

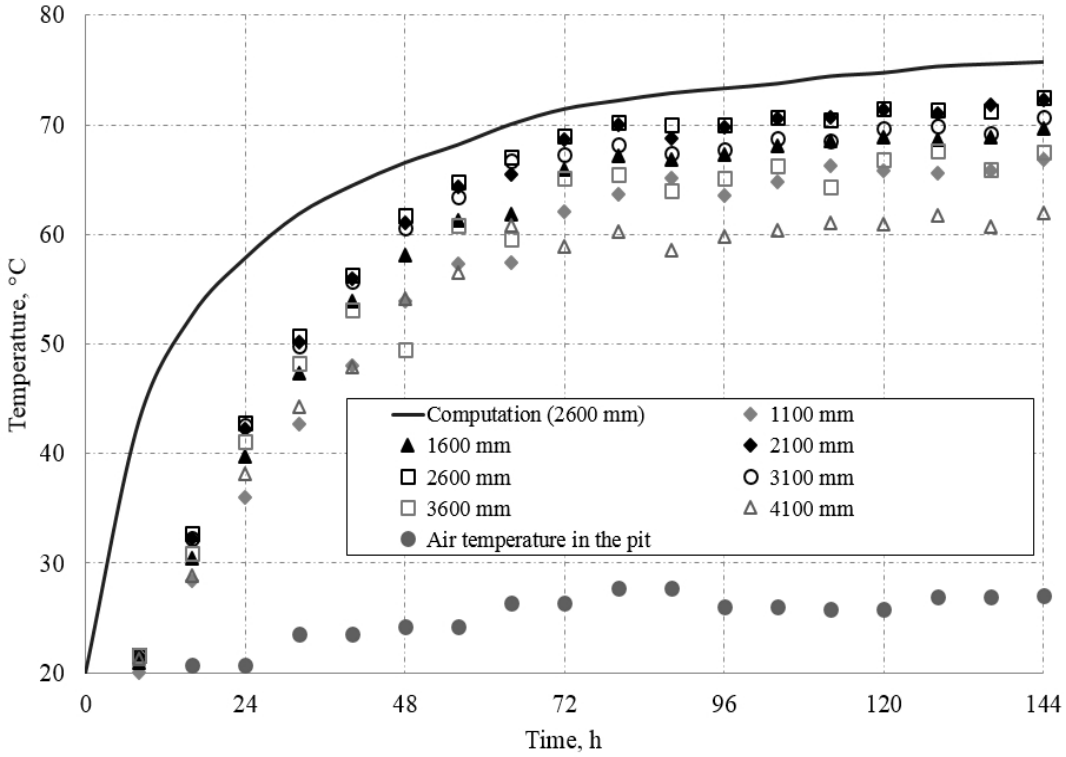
- The experimental part of the study was carried out using the developed by the authors together with the specialists of JSC "Energotex" and manufactured in JSC "Energotex" VVER-1000 SFA imitators and experimental setup

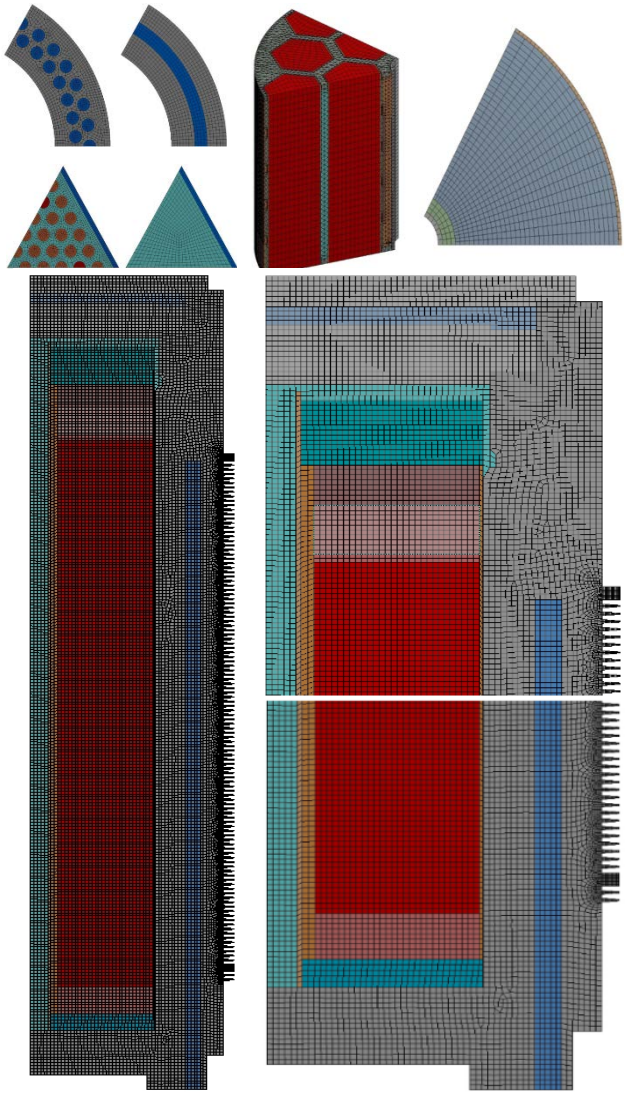




Study of thermal characteristics (2/3)

- Calculations with imitators

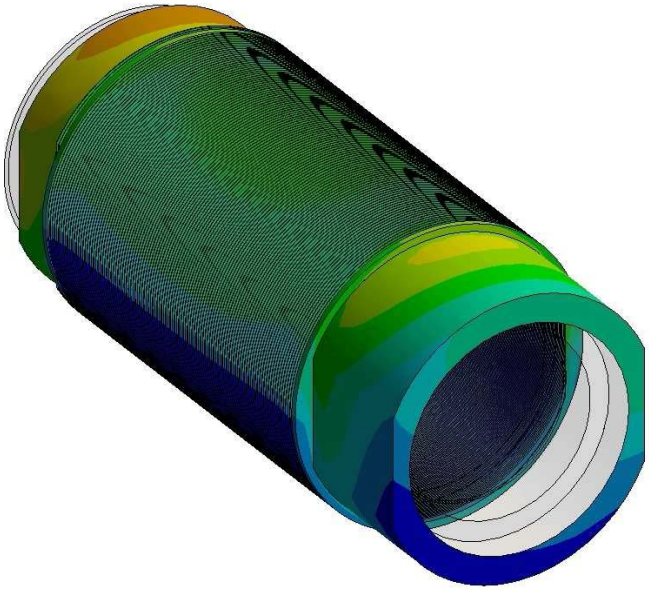


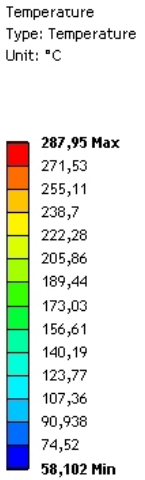


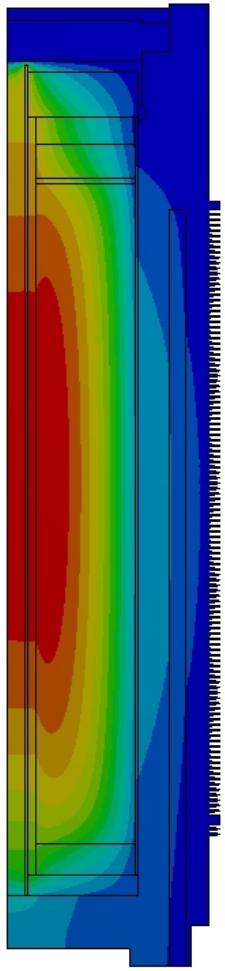
Time, h	48	72	96	120	144
Calculation, °C	62	69	70	72	72
Evaluation, °C	66	70	72	73	73
Deviation, %	+6	+1	+3	+1	+1

Study of thermal characteristics (3/3)

- Calculations with SFA







Location	Calculated, °C	Limits, °C
Cask surface	73	85
Duct surface	199	300
Inner lid seal	79	110
Fuel rod surface	293 (307)	350 (380)

Conclusions

- The independent evaluations of safety parameters is an integral and necessary part of safety assessment of nuclear facilities and activities in the field of nuclear energy. Such evaluations improve the quality of safety assessment and finally leads to increase of safety
- The quality of independent evaluations of safety parameters carried out by the technical support organizations have to be confirmed by computational or/and experimental studies of evaluated parameters
- The results of describe above computational and experimental studies of safety of VVER-1000 SNF transport in TUK-153 confirm the conservatism of using in SEC NRS approaches during preparation of computational models for independent evaluation of safety parameters during SNF transport.