# STE “NUCLEAR FUEL CYCLE” OVERVIEW

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*STE NFC*

# History

- **1994** - STE NFC was founded as a separate division of NSC KIPT for coordination and performance of NFC-related research, development, design, and engineering activities in Ukraine.
- Main STE NFC tasks are:
  - Development of Ukraine's nuclear fuel cycle concept and implementation program;
  - Scientific support for nuclear fuel cycle in Ukraine:
    - Expert evaluation of nuclear fuel;

# History

- Development of R&D and testing facilities for NFC activities;
- Research and design of fuel rods, absorbing elements, fuel assemblies for fuel manufacturing in Ukraine;
- Development of new fuel, absorbing and structural materials for high performance fuel designs;
- Development of methods, modeling and substantiation of reactor core elements;

- Collaboration in international R&D activities;
- Participation in education for nuclear industry.

# History

- STE NFC has extensive experience in fuel-related activities (oxide and metallic U fuel, absorber rods etc.) for different reactor types (RBMK, VVER, gas-cooled etc.)

(*for more details please visit* [www.crcd.kipt.kharkov.ua](http://www.crcd.kipt.kharkov.ua) *)*

$GdAlO_3$ burnable absorber rods



Fuel rods


FA for KC-150 reactor

# Quality Management

- STE NFC provide services and products for NPPs Operator in Ukraine – NNEGC “Energoatom”, for many years .
- STE NFC is approved by NNEGC“Energoatom” and Westinghouse Sweden AB as a Qualified Supplier.
- STE NFC Quality Management System is certified by TÜV Rheinland and complies with ISO 9001.2008 standard (Certificate # 01 100 1319552).

# International Cooperation

- IAEA coordinated Projects
  - “Improvement of computer codes used for fuel behavior simulation” (FUMEX-III) – PAD code validation vs TRANSURANUS and other codes;
  - “Optimization of water chemistry to ensure reliable water reactor fuel performance at high burnup and in ageing plants in 2006-2010” (FUWAC) - WWER-1000 coolant chemistry research and optimization;

# International Cooperation

- IAEA coordinated Projects
  - Research Project F1.30.15 “Conceptual development of steady-state compact fusion neutron sources” - MCNP-X calculations for sub-critical fusion-fission reactor;
  - Research Contract No. 16863/R0 “Investigation of fuel rods cladding degradation due to DHC under simulated conditions of transportation, handling, drying and consequent long-term storage in a Dry Storage Facility”;

# International Cooperation

- Fuel-related International Projects
  - Project P515 (STCU/ANL) – design and manufacture prototype of alternative fuel for the “Neutron Source” Facility with Sub-Critical Assembly at KIPT;
  - **Ukraine Nuclear Fuel Qualification Project (UNFQP)** – diversification of nuclear fuel supply sources in Ukraine;
  - **EURATOM Project NFRP 16-2015 “Supporting the licensing of Western nuclear fuel for reactors of VVER design operating in the EU”** – since 09.2015;

# UNFQP

- **Ukraine Nuclear Fuel Qualification Project (UNFQP)** goal - technical assistance for Ukraine in the area of commercial nuclear fuel diversification.

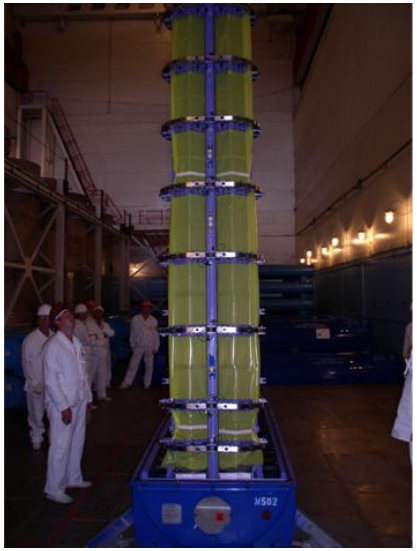
- UNFQP main tasks:
  - Training of Ukraine technical personnel
  - Delivery of equipment, documentation, computer codes;
  - Delivery of nuclear fuel - 6 Lead Test Assemblies (LTAs) and 42 Fuel Assemblies (Batch Reload);

# UNFQP

- UNFQP Milestones:
  - **1999** - Westinghouse was chosen for technology transfer and fuel manufacture;
  - **1999** - Center for Reactor Core Design (CRCD) was established as part of STE NFC at KIPT to implement UNFQP in Ukraine;
  - **2000** - Implementing Agreement between the Government of the United States of America and the Government of Ukraine was signed (extended in 2005 and 2010);

# UNFQP

- **2000-2005** - CRCD team training at Westinghouse (Pittsburgh and Columbia) in nuclear fuel design, reactor core design, safety analysis and licensing, nuclear fuel utilization, project management; participation in LTA fuel design, core design and safety analysis;
- **2005** - Westinghouse technology transfer to CRCD;
- **2005** - **2010** - 6 Lead Test Assemblies (mfd W Columbia) operation in SUNPP-3 VVER-1000;

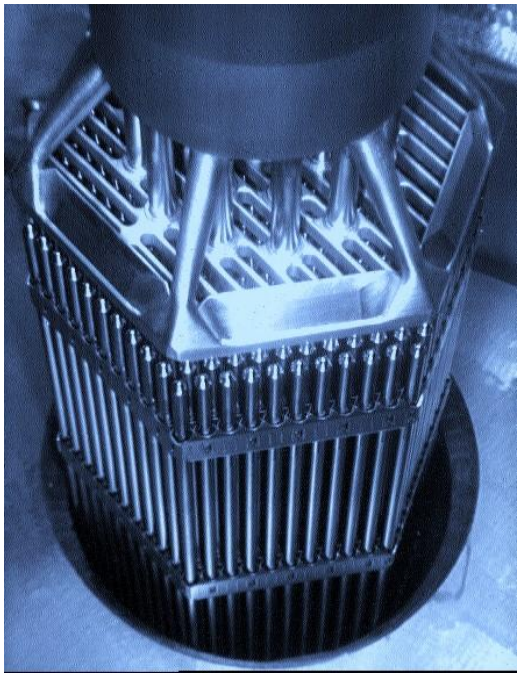


# UNFQP

- **2010 -2014** - Reload Batch of 42 WFAs (mfd W Västerås) operation in SUNPP-3 VVER-1000;

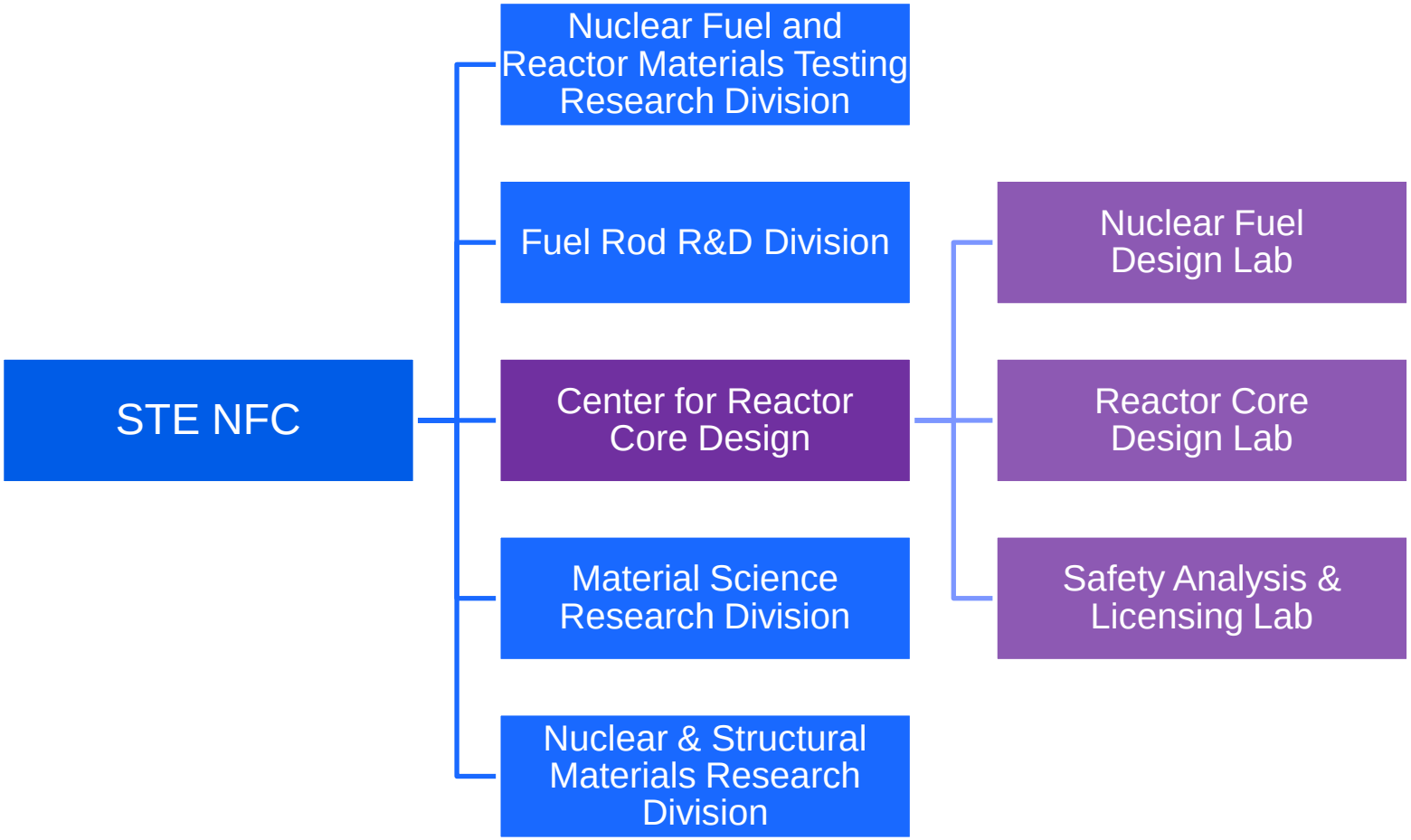
❖ **Commercial contract**

- **2011** - start of WFAs operation at SUNPP-3 and SUNPP-2;
- **2015** - start of RWFAs operation at SUNPP-3;
- **2016** - extension of RWFAs operation at SUNPP-2 and ZNPP;



RWFA – Robust WFA

# UNFQP


STE NFC
Nuclear Fuel and Reactor Materials Testing Research Division
Fuel Rod R&D Division
Center for Reactor Core Design
Material Science Research Division
Nuclear & Structural Materials Research Division
Nuclear Fuel Design Lab
Reactor Core Design Lab
Safety Analysis & Licensing Lab

# UNFQP

- CRCD staff ~25 people with experience in nuclear fuel design and operation (scientists, computer specialists, former NPP specialists).
- 8 PhDs and Doctors of science.
- 12 specialists were trained during 5 years at Westinghouse Electric Co. (Pittsburgh and Columbia divisions).
- Design tools - SolidWorks, ANSYS, SCALE, MCNP-X, NESTLE; W codes (APA, LOFTRAN, VIPRE, PAD) and CRCD designed codes.

# UNFQP

- CRCD scope of activity:
  - W fuel (UNFQP and commercial batches) operation support at Ukrainian NPPs;
  - Criticality and radiation safety analyses;
  - Thermohydraulic, neutronic, mechanical, fuel rod design calculations;
  - Safety analysis;
  - Computer codes modification and development;

# EURATOM Projects

- EURATOM Project NFRP 16-2015 “Supporting the licensing of Western nuclear fuel for reactors of VVER design operating in the EU” goal – establishing all necessary safety analyses, tests and procedures in view of the further licensing of VVER fuel manufactured by Western suppliers.
- STE NFC participates in a Project as a part of consortium, including Westinghouse/VUJE/NRI/ LUT/NNL/ NucleoCon/JRC/Enusa.

# EURATOM Projects

STE NFC collaborates in several Work Packages (WP):

- WP2 “Development of a licensing analysis scope”
- WP3 “Fault analysis”
- WP4 “Fuel rod design”
- WP5 “Thermal Hydraulic design”
- WP6 “ANC-H validation for VVER-440”
- WP7 “Nuclear criticality safety analyses for VVER-440”
- WP8 “Dissemination and exploitation of results &interactive communication”

# EURATOM Projects

## WP2 “Development of a licensing analysis scope”

- Interact with utilities and regulator organizations to define the analysis scope for VVER-440 alternative fuel licensing in respective countries
- Technology areas shall be evaluated (as a minimum):
  - LOCA and non-LOCA Safety Analyses;
  - Radiological Analyses;
  - Nuclear Criticality Safety;
  - Mechanical Design;
  - Nuclear and Core Design;
  - Fuel Rod Design;
  - Thermal Hydraulic Design

## STE NFC expertise

- SUNPP-2,3 and ZNPP-5 SARs for Westinghouse FAs implementation (VVER-1000)
- SUNPP-3 and ZNPP-5 SARs for Robust WFAs implementation (VVER-1000)
- RNPP-1,2 spent fuel pool SAR (VVER-440)

# EURATOM Projects

## WP3 “Fault analysis”

- Safety analysis codes coupling and integration with TRANSURANUS (TU)
  - TU-DYN3D
  - DYN3D-ATHLET
  - TU-ATHLET or TU-RELAP
  - TU-SERPENT-COMSOL
- Developing analysis methodology
- Validation and benchmarking for selected safety analyses

## STE NFC expertise

- FUMEX-III participation (TU vs PAD comparison)
- NESTLE and LOFTRAN coupling experience

# EURATOM Projects

## WP4 “Fuel rod design”

- Developing analysis methodology and validation of chosen FRD code
- Developing a FUDDL interface to APA-H

## STE NFC expertise

- FUMEX-III participation (TU vs PAD comparison)
- APA-H usage for core design

FRD – Fuel Rod Design
FUDDL – Fuel Design Data List

# EURATOM Projects

## WP5 “Thermal Hydraulic design” objectives

- Develop a methodology for T/H calculations
- Evaluate the feasibility of the Smolin as well as the Bezrukov correlations for the proposed VVER-440 fuel design.
- Validate their implementation in VIPRE.
- Evaluate the need for additional DNB testing and/or alternative correlations.
- Create and validate a VVER-440 model in VIPRE-W code
- Implement applicable DNB correlations into applicable T/H codes

## STE NFC expertise

- VIPRE-W usage for VVER-1000  T/H analysis
- VIPRE-W modification experience

# EURATOM Projects

## WP6 “ANC-H validation for VVER-440”

- Validation of APA-H (PHOENIX-H and ANC-H) for VVER-440 calculations to enable core design work with this code package

## STE NFC expertise

- ANC-H usage for VVER-1000 core design
- ANC-H modification experience

# EURATOM Projects

## WP7 “Nuclear Criticality Safety (NCS) Analyses for VVER-440”

- Development of NCS Methodology for VVER-440
- Validation of NCS Methodology for VVER-440

## STE NFC expertise

- SCALE and MCNP-X usage for VVER-1000 (SUNPP, ZNPP) and VVER-440 (RNPP) NCS analyses
- Uncertainty assessment experience

# EURATOM Projects

## WP8 “Dissemination and exploitation of results & interactive communication”

- Review of the chosen design concept
- Communication with utilities and regulatory bodies

## STE NFC expertise

- Westinghouse VVER-1000 fuel licensing experience in Ukraine
- Well-established communication with NPPs and SNRIU

# Conclusions

- STE “Nuclear Fuel Cycle”
  - unique experience on nuclear fuel cycle issues in the past and the present day.
  - experienced personnel and powerful tools for engineering, design and research activities.
  - active participation in the nuclear-related international projects.
- HORIZON 2020 - new opportunities for STE NFC.

# Thank you!

# Backup files

- CRCD-designed tools
  - CAT (**C**alculation **A**utomation **T**ool) – routine neutronuc calculations automatization
  - FAST (**F**uel **A**ssembly **S**huffling **T**ool) – fuel loading pattern selection and optimization
  - CMP (**C**ore **M**ap **P**rocessing) – fuel loading sequence optimization
  - NETRAN (**NE**STLE+LOF**TRAN**) – coupled neutronic and thermohydraulic code for safety analysis
  - DiFis - neutron kinetic code utilizing FEM

FEM – finite elements method