Safety Reassessment of Ukrainian Research Reactors in the Light of the Lessons Learned from the Fukushima Daiichi Accident

Andrii Shepitchak
State Nuclear Regulatory Inspectorate of Ukraine

Oleksii Dybach, Oleksandr Kukhotsky
State Enterprise "State Scientific and Technical Center for Nuclear and Radiation Safety"

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Introduction

Nuclear power is important component of fuel and energy complex of Ukraine (up to 60% in total electricity production). Nuclear power units:

- 15 (VVER-440&1000) – are in operation at 4 sites;
- 3 (RBMK-1000) – are in decommissioning at Chernobyl NPP (obtained status of radioactive waste management facility because nuclear fuel was removed).

There are 2 SF storages are in operation:

- ISFS (dry) at Zaporizhzhia NPP;
- ISFS-1 (wet) at Chernobyl NPP and
- ISFS-2 (dry) at Chernobyl NPP - under commissioning;
- Centralized SFSF (dry) – under construction





Introduction (cont)

Except NPPs and SFSF Ukraine has:

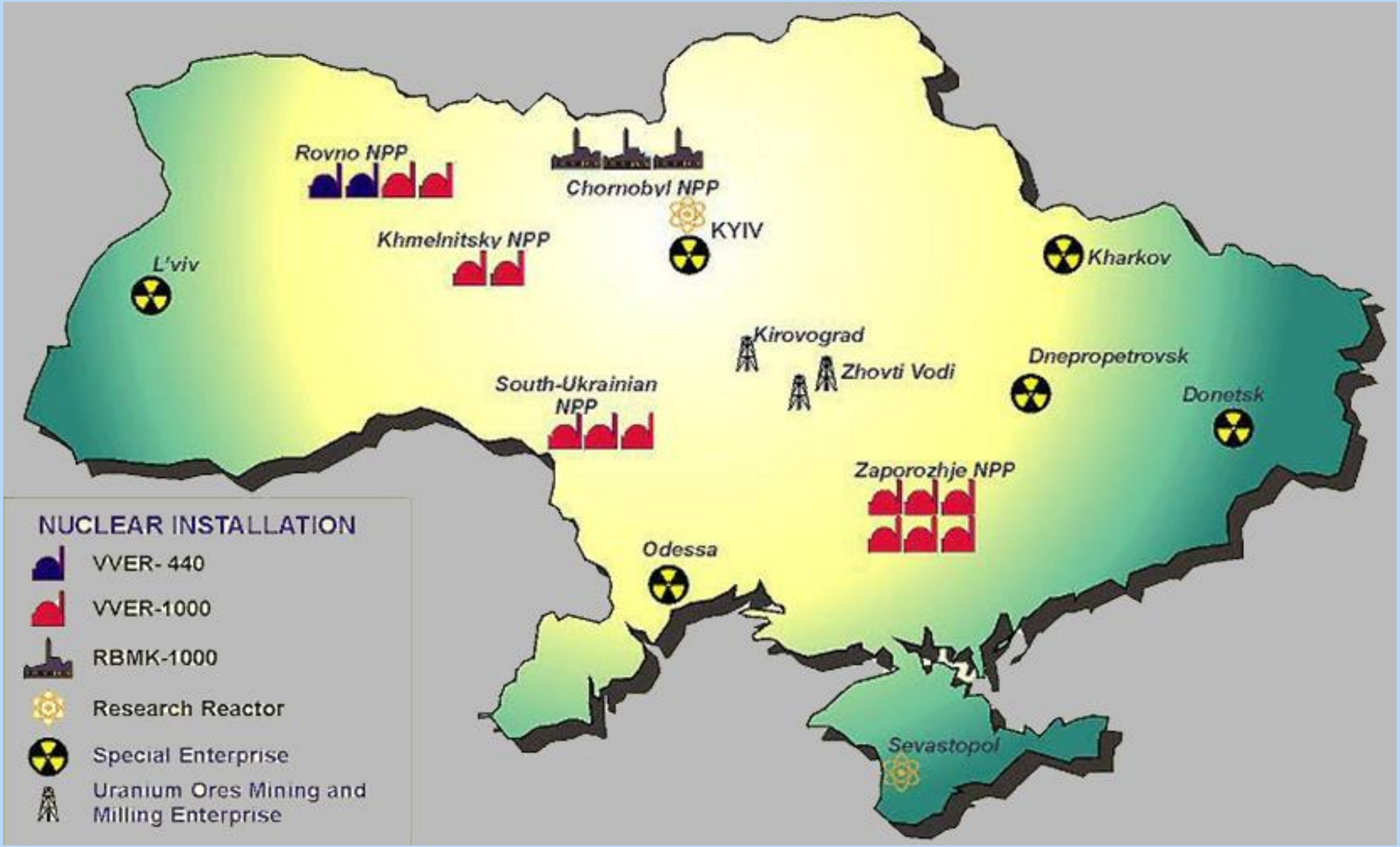
- two research reactors (hereinafter - RRs):

WWR-M which are located on sites of Kyiv Nuclear Research Institute (hereinafter - NRI) of the National Academy of Sciences of Ukraine;

IR-100 which are located on sites of Sevastopol Nuclear Energy and Industry University;

- physical test bench and subcritical uranium-water assembly which are located on sites of Sevastopol Nuclear Energy and Industry University.

Introduction (cont)



WWR-M

- The research reactor has operated since 1960.
- WWR-M is a light-water moderated and cooled tank reactor with forced cooling. The maximum reactor power is 10 MW.
- Fuel - UO_2-Al. In the beginning the assemblies used were 90% enriched WWR-5M, WWR-7M fuel type, supplied by Russia. Then the reactor core was composed of 36% enriched WWR-2M fuel assemblies, supplied by Russia too. **Now the fuel enrichment is limited to 20%.**

- Taking into account the results of periodic safety review (including results of stress-test) the operational period of WWR-M was extended till 31 December 2023.

IR-100

- The IR-100 reactor is heterogeneous thermal neutron pool type research reactor which uses pure ordinary water as coolant and moderator.
- Physical reactor start up was performed on April 18, 1967;
- In 1973 reactor nominal power was increased up to 200 kW;
- Nuclear fuel: UO_2 enriched up to 10% with ^{235}U;
- The operation period of IR's "critical" elements were justified till the end of 2012. Therefore SNRIU required developing the Periodic Safety Review Report from OO.

- The license on operation of IR-100, physical test bench and subcritical uranium-water assembly was suspended in 16 June 2014 taking into account temporarily occupation of Crimea by Russian Federation. Such decision was made due to systemic violation of Ukrainian laws and SNRIU guidelines by OO .

Concept for building a New Multipurpose RR

- The Concept for Building a New Multipurpose Research Reactor was developed by the specialists of NRI and approved by Cabinet of Ministers of Ukraine (Decree №1299-r from 8 October 2008).

- The Concept sets basic requirements for designing, constructing and operating the new research reactor in Ukraine.

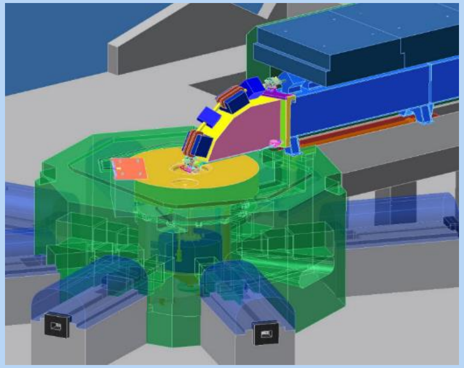
- It was expected that New multipurpose research reactor becomes the base installation of the new research nuclear center.

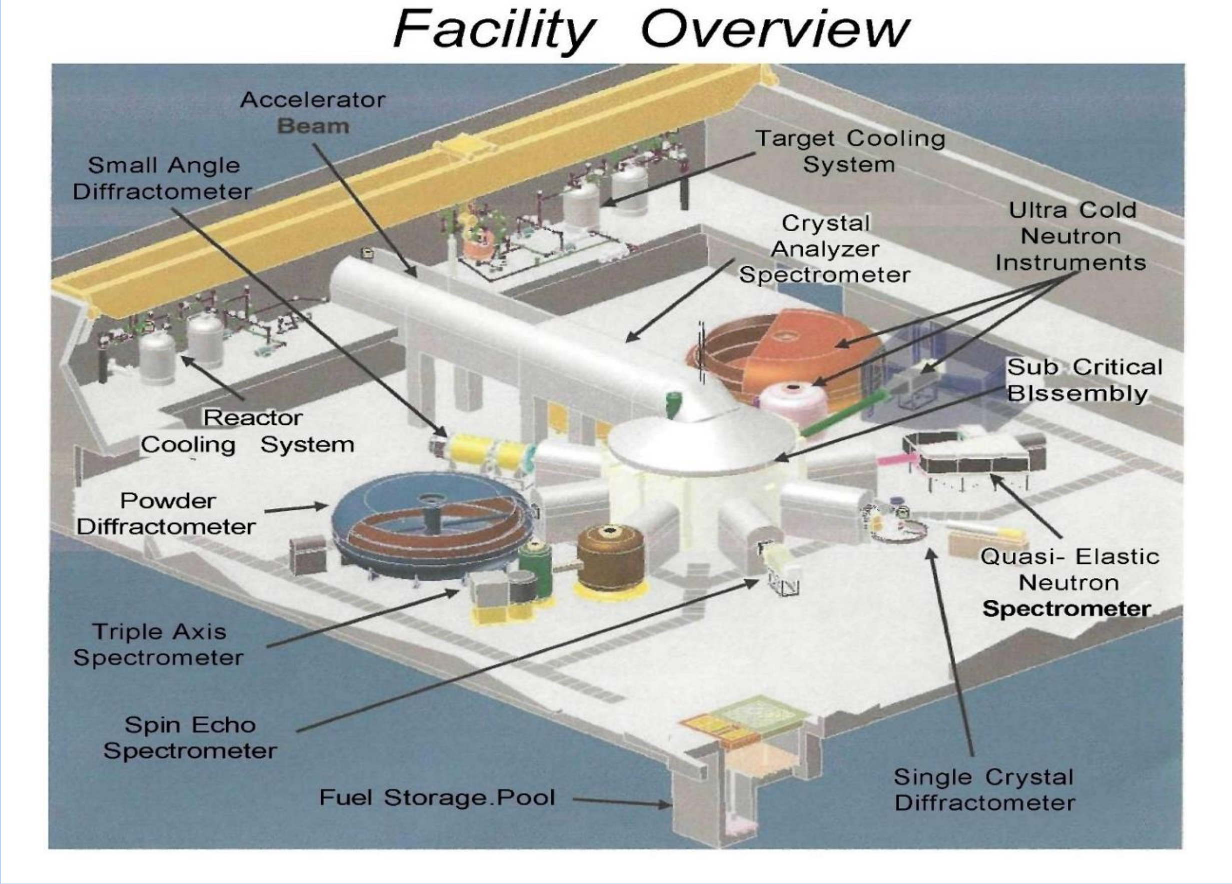
- On the current time SNRIU has not obtained any documents concerning this project.

Neutron source

The National Science Centre Kharkov Institute of Physics and Technology of the National Academy of Sciences of Ukraine (NSC KIPT) is constructing a Neutron Source Based on an Electron Accelerator-Driven Subcritical Assembly (hereinafter - NS).

Construction of the NS is financed by U.S. Department of Energy in the frame of the Russian Research Reactor Fuel Return (RRRFR) program.





Neutron source (2)

Current status:

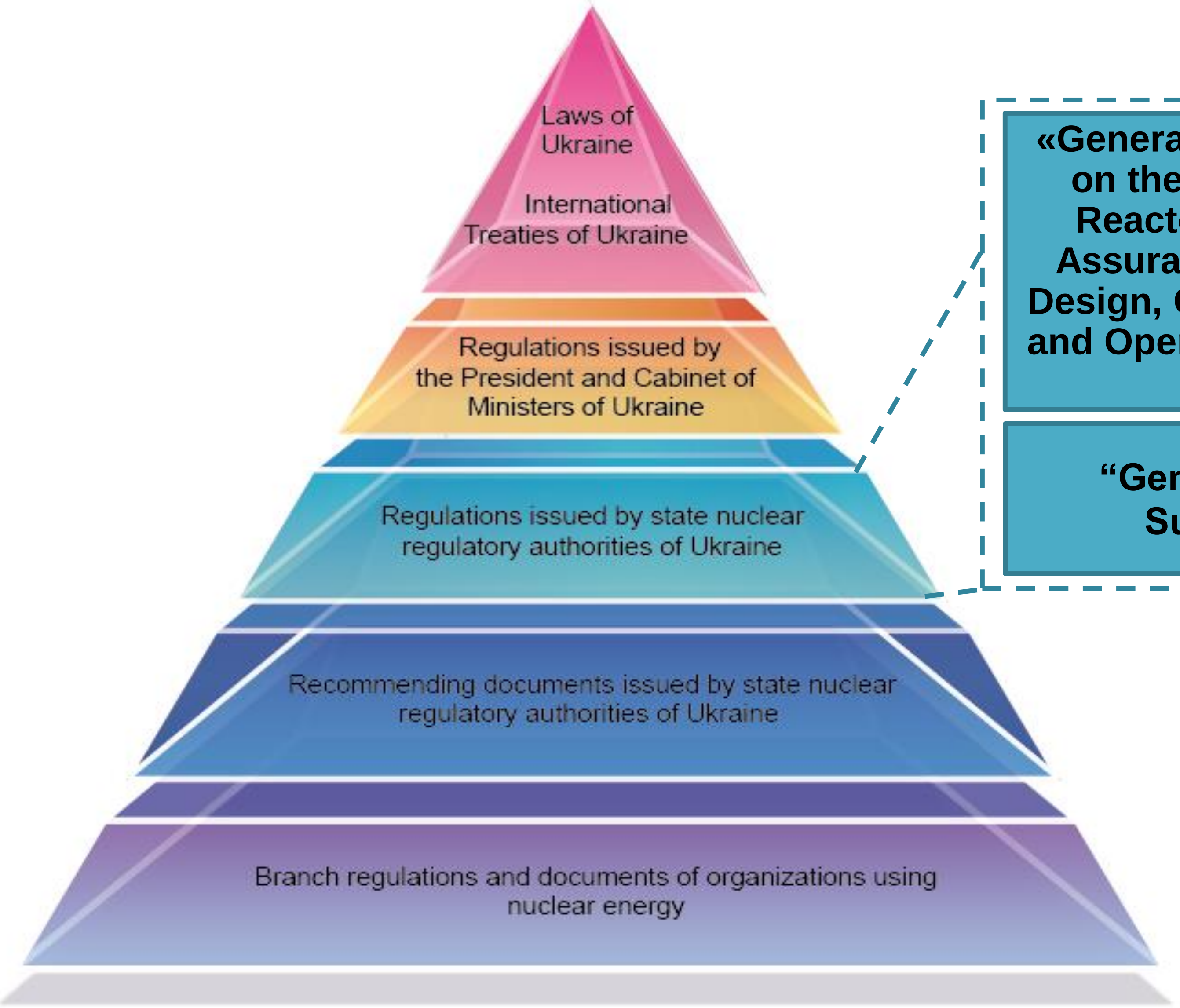
- all construction activities have been completed;
- mounting of all equipment and process systems have been completed;
- for 5 out of 18 systems important to safety individual and functional tests were completed;
- automated systems of radiation and individual dose monitoring have been put into service;
- nuclear fuel for NS is located at Research reactor in Kyiv

Neutron source (3)

- Next steps:
  - completion of the individual tests of all process systems
  - integral tests (with the fuel assemblies imitators)
  - first nuclear fuel delivery to the KIPT site
  - core loading and physics tests
  - commissioning and starting of the trial operation
- Basic documentation are to be provided according to the Licensee conditions:
  - updated PSAR
  - emergency operating procedures
  - Tech. Specification
  - set of the operational documentation for safety related system

- The schedule of the NS commissioning was refined by KIPT to reflect the current status. The commissioning date was postponed on 2018

Hierarchy of normative documents



«General Provisions on the Research Reactors Safety Assurance During Design, Construction and Operation» (OPB IR)

«Rules on Nuclear Safety of the Research Reactors» (PBYA)

“General Safety Provisions for Nuclear Subcritical Assembly” (OPB NSA)

“Requirements for structure and contents of PSAR current NPPs”

Legislative framework for research installations

The OPBs define general requirements for all stages of the research nuclear installations (RRs and NS) lifecycle. Some requirements should be specified in other RD of lower level.

If foreign documents are used in the process of safety justification of nuclear installations, it is necessary to ensure harmonization of their requirements with Ukrainian framework in the sphere of nuclear energy. International regulations and rules may be used, if:

a) their requirements are more conservative;

b) aspects which are not reflected in national regulatory documents need to be addressed.

Comparative analysis of regulatory documents (analysis of compliance) should be submitted to the SNRIU for consideration.

Legislative framework on lifetime extension of RRs

- Ukrainian legislation has no specific requirements or guidance concerning lifetime extension of RRs and preparing the Periodic Safety Analysis Report.

- In this case OOs based on the recommendations of SNRIU used industrial document “Requirements for structure and contents of PSAR for current NPPs”.

- Additionally it was recommended to use the IAEA standards related to safety of RRs: NS-R-4 “Safety of Research Reactors”, NS-G-4.2 “Maintenance, Periodic Testing and Inspection of Research Reactors”, 35-G1 “Safety Assessment of Research Reactors and preparation of the Safety Analysis Report safety Guide”.

- During this process the specificity of each RR was taken into account (graded approach).

Improving of legislative framework

- All in force regulatory documents in Ukraine which define approaches for ensuring of nuclear safety of RRs, inter alia, OPB IR and PBYa, were developed in former Soviet Union.

- The new Concept for Regulation of Nuclear and Radiation Safety of Nuclear Facility has been approved by the decision of the Joint Board Meeting of SNRIU (dated 19.03.2015 #2).

- It is envisaged in the Concept to build a new structure of Ukrainian legislative framework in the field of nuclear and radiation safety of Nuclear Installations. The main idea of the Concept is to outline the same general provisions for all types of nuclear installations in a single regulation and develop new specific regulations for each type of nuclear installations (including Nuclear Fuel Fabrication Plant, SNFSF, Sub-critical assemblies, Research Reactors etc.).

- The draft of new regulations on safety of RRs has been developed. But since IAEA have published a new document SSR-3 and it is expected to publish the guidance on periodic safety review of RRs, there is a need to harmonize the developed draft with up-to-date international IAEA standards and it should correspond to newly adopted Concept.

Improving of framework (cont)

GENERAL PROVISIONS FOR ALL TYPES OF NUCLEAR INSTALLATIONS (Task A1)

- Safety Provisions for Nuclear Fuel Fabrication Plant **(Task A1)**
- Safety Provisions for Nuclear Sub-critical Facility **(Subtask 2.1)**
- Safety Provisions for Interim Storages of Dry Spent Nuclear Fuel **(Subtask A 3.2)**
  - Requirements for scope of the SAR and PSR of Interim Storage **(Subtask A 3.2)**
- Safety Provisions for Research Reactors **(Subtask A 4.1)**
  - Regulation on the report of PSR for RRs **(Subtask A 4.1)**
    - Regulation on the **investigation of operational events at** RRs, critical and subcritical assemblies **(Subtask A 4.2)**

Stress-tests

- After the Fukushima-Daiichi accident, Ukraine joined the initiative of the European Commission and European Nuclear Safety Regulatory Group (ENSREG) regarding performing stress tests for NPP units and spent fuel storage facilities based on the ENSREG stress test and peer review specifications (Declaration on Stress Tests, 24 June 2011).
- In this period, both of Ukrainian RRs were under the process of lifetime extension. Therefore State Nuclear Regulatory Inspectorate of Ukraine required Operating Organizations to carry out the complimentary assessment and to combine it with Periodic Safety Review for the RRs.
- The OOs had to perform additionally assessment in detail:
  - external extreme natural events (earthquakes, flooding, fires, tornadoes, extremely high/low temperatures, extreme precipitations, strong winds, combinations of events);
  - loss of electrical power and/or loss of ultimate heat sink;
  - severe accident management.

Stress-tests results

- SNRIU took into account the results of stress-tests during the assessment process of OO’s application on the lifetime extension of WWR-M. According to the results of "stress-tests" a set of measures for improving of RR’s safety was developed and implemented.

- The safety reassessment process and stress-tests were not finished for IR-100, since the territory where the research reactor is located has been temporary occupied for the last several years.

- Additionally the lessons learned from Fukushima-Daichi accident have been taken into account during the safety justification of NS.

Stress-tests results of WWR-M (1)

- An accident involving primary piping rupture and total blackout that may occur under a combination of natural hazards (earthquake, tornado) and/or human errors has been analyzed as the basic, most representative accident scenario.

- It is demonstrated that redundancy of heat removal from the nuclear research reactor can be ensured by regular systems and equipment and a mobile pump (flow rate to 30 m^3/h), and power supply to safety systems can be additionally provided by a diesel generator (120 kW).

- It is shown that a combination of external and man-induced factors in excess of the limits incorporated in the reactor design will not affect accident management capabilities and systems and components will ensure safety of the nuclear research reactor.

Stress-tests results of WWR-M (2)

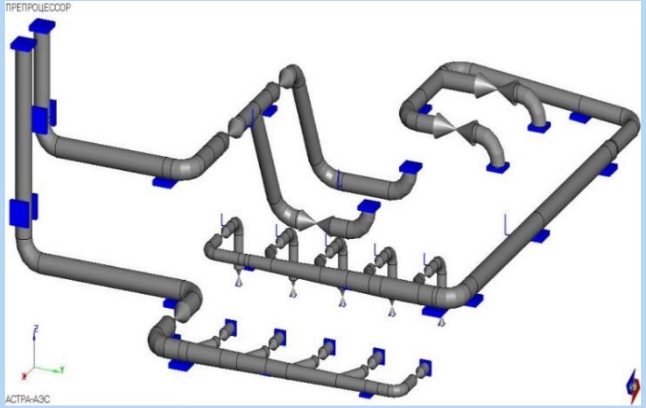
- ✓ There are no other facilities nearby (factories, plants, other hazardous enterprises) that may affect on the reactor in case of accidents at them.

- ✓ Upon stress-tests, a series of safety improvement measures have been developed for the nuclear research reactor. The measures has been completed: purchased a pump and fire hoses to supply service water from the pump to the reactor core, purchased electric cables and valves for power supply to reactor systems from the diesel generator in emergencies, etc.

Main modernizations of WWR-M

The main previous modernizations of WWR-M:

- Replacement of the heat exchanger of the primary circuit
- Replacement of control and protection system and control instrumentation system on equipment of industrial-technical complex of automatic regulation, control, management and protection.
- Replacement power and control cables.
- Modernization of spent fuel management system.
- Modernization of emergency cooling system
- Replacement of the elements of the reactor radiation control, emergency generators, battery.
- Replacement of research reactor from HEU to LEU.
- Installation of fire alarm system.
- Replacement of the individual sections of the primary piping.



Requirements of NS safety justification (1)

The preliminary list of initiating events for the NS design and for safety justification in the safety analysis report according to OPB NSA Annex should include:

1. Design-basis accidents

1.1. Initiating events that lead to insertion of positive reactivity of the Neutron Source: drop of an item that inserts positive reactivity into the NS core; insertion of positive reactivity by control rod actuators, process systems or experimental devices due to failures or personnel errors; unscheduled change of geometry and state of the core components, reflector; failure, damage of the NS internals (components); injection of cold (hot) coolant into the core; personnel errors during nuclear fuel loading, etc.).

1.2. Initiating events that lead to heat removal failure: blocking of coolant when passing through fuel rods, failure of the NS cooling systems; leak of the NS casing; heat exchanger leakages; equipment depressurization or ruptures of experimental device piping; dewatering of the NS core, spent fuel pool (SFP).

Requirements of NS safety justification (2)

1.3. Initiating events related to failures during treatment of nuclear materials (NM) (damage of separate fuel rods; drop of fuel rods or experimental device with nuclear materials, drop of items into spent fuel pool, etc.).

1.4. Natural and man-made events: seismic impacts; internal and external fires at the Neutron Source site; flooding of the premises.

2. Beyond design-basis accidents

2.1. Accidents with unauthorized insertion of positive reactivity when several failures or personnel errors are combined.

2.2. Accidents with total loss of external power supply with failure of the confining system or personnel errors related to its control.

2.3 Accidents with increased heat generation in NGT due to unauthorized increase of charged particles flow and failure of cooling system in combination with failure of the confining system or personnel errors related to its control.

Expert assessments of the NS documents

The SNRIU with SSTC NRS involvement performed expert assessments of the preliminary safety analysis report and design documents for the NS.

The following conclusions were made in the expert assessments.

The defense-in-depth strategy has been implemented in the NS. This strategy is based on a system of safety barriers to prevent releases of ionizing radiation and radioactive substances into the environment and a system of technical features and organizational measures to protect the safety barriers and preserve their efficiency. The safety barriers include the fuel rod claddings, primary system, confinement system.

The NS design properly considers the lessons learnt from the Fukushima accident (safe shutdown earthquake of magnitude 7 on the MSK-64 scale is accepted in the design to ensure an adequate seismic margin in relation to the site seismicity of MSK-64 magnitude 6).

The accident analysis confirmed that safety of the NS would be ensured in case of loss of heat removal and total blackout.

Conclusions

- The results of RRs stress-tests were taken into account during the assessment process of OO's applications on the lifetime extension of RRs.
- Upon stress-tests, series of safety improvement measures have been developed for the WWR-M and have been completed.
- The safety reassessment process and stress-tests were not finished for IR-100. The license on operation was suspended in 16 June 2014.
- The lessons learned from Fukushima-Daiichi accident have been taken into account during the safety justification of NS and the NS design properly considers it.

THANK YOU FOR ATTENTION!

Questions?