SAFETY IMPLICATIONS ON THE BACK END OF THE FUEL CYCLE FOR SMRS

S. Bznuni

Nuclear and Radiation Safety Center

NRSC

S.Bznuni@nrsc.am

Background

- SMRs could offer substantial advantages vs conventional LR
  - advanced safety features
    - reliance only on passive safety systems
  - enhanced flexibility in deployment
    - construction phase in mainly moved to manufacturing
  - enhanced manoeuvrability in operation
    - Increased load-follow capabilities

- Many SMR designs consider use of fuel with enrichment higher than 5% threshold that could have significant implications on the back-end of fuel cycle

Validation of Simulation Tools

- Spent fuel modeling tools and related nuclear data libraries used in
  - criticality safety
  - source term
  - decay heat
  - shielding

  for LWR fuel analysis were validated mainly based on experiments with enrichments less than 5%.
- Validation of modeling should be extended
- New experiments involving both fresh and spent fuel assemblies with enrichments higher than 5% should be carried out to support validation

Transport of Spent Fuel Assemblies (1/2)

- Due to criticality safety
  - design changes
    - adding additional neutron absorbers
    - Increasing spacing of fuel assemblies
  - limiting the number of fuel assemblies that could be loaded into transport containers
  - applying burnup-credit approach
    - depletion codes used to feed criticality safety codes with spent fuel isotopic data were mainly validated based on spent fuel chemical assay data having enrichment less than 5% and burnups less than 62 GWd/tU
    - criticality codes and nuclear data libraries were validated for <5% enrichments

Transport of Spent Fuel Assemblies (2/2)

- Due to decay heat
  - design changes to handle the increased thermal load
  - limiting the number of fuel assemblies that could be loaded into transport containers
  - Increasing pre-cooling time in spent fuel pool
    - could lead shortage of available spent fuel loading spaces to meet regulatory requirement on emergency full core unloading
- Due to neutron and gamma dose rates
  - design changes with enhanced shielding features
  - limiting the number of fuel assemblies that could be loaded into transport containers
  - Increasing pre-cooling time in spent fuel pool
    - could lead shortage of available spent fuel loading spaces to meet regulatory requirement on emergency full core unloading

Storage of Spent Fuel Assemblies (1/3)

- Due to criticality safety
  - design changes
    - adding additional neutron absorbers
    - Increasing spacing of fuel assemblies
  - limiting the number of fuel assemblies that could be stored in storage modules or storage casks
  - applying burnup-credit approach
    - depletion codes used to feed criticality safety codes with spent fuel isotopic data were mainly validated based on spent fuel chemical assay data having enrichment less than 5% and burnups less than 62 GWd/tU
    - criticality codes and nuclear data libraries were validated for <5% enrichments

Storage of Spent Fuel Assemblies (2/2)

- Due to decay heat
  - design changes to handle the increased thermal load
  - limiting the number of fuel assemblies that could be loaded into storage module or storage casks
  - Increasing pre-cooling time in spent fuel pool
    - could lead shortage of available spent fuel loading spaces to meet regulatory requirement on emergency full core unloading
- Due to neutron and gamma dose rates
  - design changes with enhanced shielding features
  - limiting the number of fuel assemblies that could be loaded into transport containers
  - Increasing pre-cooling time in spent fuel pool
    - could lead shortage of available spent fuel loading spaces to meet regulatory requirement on emergency full core unloading

Storage of Spent Fuel Assemblies (3/3)

- Thermo-mechanical considerations
  - The higher fuel rod burnup can potentially cause more
    - corrosion
    - hydrogen uptake
    - more fission gas release from the fuel.
  - Potentially increased corrosion and hydrogen uptake could negatively influence on safe transport and storage of spent fuel
  - Radiological consequence analysis for spent fuel pools should be re-evaluated due to increased fission gas in the fuel rods.

Conclusions

- Increased fuel enrichment and consequently burnup could cause challenges in both transportation and storage of SMR spent fuel assemblies
- All mentioned issues should be thoroughly and comprehensively addressed by designers and vendors to have a smooth licensing process.

ARMENIAN SCIENTIFIC-RESEARCH INSTITUTE FOR NPP OPERATION
CJSC «ARMATOM»
www.armatom.am

IMPORTANT ASPECTS OF FUEL CYCLE TO BE CONSIDERED DURING DEPLOYMENT OF NEW NUCLEAR POWER TECHNOLOGIES IN THE REPUBLIC OF ARMENIA

VAHRAM PETROSYAN,
General Director,
Professor, Doctor of Sciences (Engineering),

Technical Meeting on Back End of the Fuel Cycle Considerations for Small Modular Reactors
Vienna, Austria
20–23 September, 2022

FUTURE OF NUCLEAR ENERGY IN THE COUNTRY

According to the country's current strategic plan of energy sector development (for 2015-2036), a nuclear power unit necessarily must be part of the electricity generation installations structure. This is dictated not only by the Concept of the Energy Security of the country but also by need to meet the goal of minimizing the greenhouse gas emissions.

The strategic plan foresees the activities for second lifetime extension of the existing nuclear power unit in operation – additional 10 years (from 2026 to 2036). Before 2036 a new nuclear power unit (units) as replacing capacity must be commissioned.

The new nuclear unit should be a PWR or a SMR unit based on the pressurized water reactors' technologies. Country's nuclear energy infrastructure is most appropriate to "host" a new nuclear unit (or units) based on the pressurized water reactors' technologies. Drastic change of technologies (compared to operated WWER technology) is not acceptable or, at least, not desirable.

A midpower nuclear plant (about 600 MWe) is considered to be deployed.

Currently 3 possible technological options could be realistic for Armenia:

- A mid size PWR unit with about 600 MWe capacity;
- 2 small size PWR units with about 300 MWe capacity each one;
- Several SMRs.

No specific type of MSR is currently considered. An overall study of possible options is underway.

IMPORTANT ASPECTS OF FUEL CYCLE OF NEW NUCLEAR POWER TECHNOLOGIES

It is a fact that small modular reactors (SMRs) often require adjustments or new developments for the fuel cycle. Many studies have shown that SMRs are incompatible with existing nuclear waste disposal technologies and concepts. Advanced fuels proposed for SMRs may pose different challenges, including the long term management of used fuel and radioactive waste.

According to the results of several studies on the implications of SMRs for the back end of the nuclear fuel cycle and on the radioactive waste stream characterization, the SMRs will produce more voluminous and chemically/physically reactive waste than PWRs, which will impact the options for the management and disposal of this waste. It is anticipated that the volumes of spent nuclear fuel also will significantly increase in case of SMR implementation.

As Armenia consider implementation of SMRs, as one of the options of future electricity generation installations, the concepts of fuel cycles for SMRs are important since it can create challenges in spent fuel and radioactive waste management.

The spent fuel from the existing nuclear power unit in operation, after unloading from reactor core, is stored for several years in spent fuel pools, then transferred to dry storage facility for long-term storage.

IMPORTANT ASPECTS OF FUEL CYCLE OF NEW NUCLEAR POWER TECHNOLOGIES

The SNF dry storage facility design is based on the NUHOMS standard design – version NUHOMS-56V. The NUHOMS system provides storage of SNF assemblies in dry, horizontally placed canisters. The canisters, in turn, are located in storage modules made of reinforced concrete. The modules are arranged in two rows, each of them is closed by an armored door (see picture 1).

Removal of residual heat during storage is carried out by natural air circulation and heat exchange through the walls and roof of the horizontal storage module (HSM). HSM is a small reinforced concrete structure designed for normal and extreme loads.

The first stage of the SNF dry storage facility was provided for the storage of 616 pcs. of spent fuel assemblies that remained at the ANPP after the collapse of the USSR and were not taken out for processing. In connection with the collapse of the USSR the design scheme for the shipment of spent fuel was violated.

The filling of the 11 HSMs of the first stage was completed in the period from August 2000 to April 2004.

IMPORTANT ASPECTS OF FUEL CYCLE OF NEW NUCLEAR POWER TECHNOLOGIES

To accommodate the spent fuel assemblies unloaded from the reactor core after the resumption of operation, it was decided to expand the existing storage facility and build the second stage of the storage facility.

The first part of the second stage was put into operation in 2008. It is currently full. The second part of the second stage was put into operation in 2016. Currently, out of 12 HSMs, 9 are filled.

Thus, as of December 2021, 32 out of the 35 HSMs available at the dry storage facility were filled. The number of spent fuel assemblies stored at the facility is 1792.

Pic. 1. External view of ANPP SNF dry storage facility

In 2023, it is planned to build the third stage of the dry storage facility, consisting of 12 modules. To accommodate all spent fuel assemblies, considering the plant operation till 2036, it will be necessary to build another fourth stage of the spent fuel dry storage facility (before 2035). The project of the fourth stage is under discussion. Apparently, dual-purpose vertical containers will be used there.

IMPORTANT ASPECTS OF FUEL CYCLE OF NEW NUCLEAR POWER TECHNOLOGIES

Management of spent nuclear fuel is one of the most important issues to be solved during the planning of deployment of new nuclear technologies in Armenia. In the process of consideration of the different options of new nuclear technologies, another key aspect is the characteristics of the fuel cycle from the point of view of anticipated radioactive waste streams. The requirements and constraints for spent fuel and radioactive waste intermediate and final disposal applicable to SMR fuel cycle are within the critical factors when making decision on deployment of new nuclear technologies in the country.

Another key aspect is the levelized cost of electricity (LCOE) which, in turn, is directly or indirectly influenced by the fuel cycle concept.

When specific designs of SMRs are considered for deployment, detailed study of higher mentioned aspects will be of high priority.

THANK YOU FOR ATTENTION