Федеральное государственное учреждение
"Научно-технический центр по ядерной и радиационной безопасности"

Licensing Support Experience of the BN-600 Operation

N. Khrennikov, A. Sintsov
SECNRS, Rostechnadzor, Russia
sintsov@secnrs.ru

International Conference on Fast Reactors and Related Fuel Cycles: Safe Technologies and Sustainable Scenarios (FR13), 4-7 March 2013, Paris, France

- ✓ On April 8, 2010 there was 30th anniversary from the start-up of the 3rd power unit of the Beloyarsk nuclear power plant with the reactor BN-600.

Beloyarsk NPP (units 3) BN-600 past, today and future

- ✓ no depressurized pins;
- ✓ negligible long-living gases and noble gases release;
- ✓ last sodium leakage was in May, 1994 year;
- ✓ no leaks in the steam generators in last 19 years:
- ✓ no refusals of sodium equipments. In last years the refusals took place only in equipment of the third cycle and power supply systems;
- ✓ no actuation of the emergency protections for the last 9 years (from 2001 to 2009).
- ✓ Average operational factor is 74 % and it was generated about 112 billion kWh energy for 30 years.

Beloyarsk NPP (units 3) BN-600 past, today and future

- ✓ For the last time it was tested, replaced and repaired main equipments of the 1 and 2 sodium cycles (for example, main circulation pumps, steam generators, heat exchangers, rotating plugs).
- ✓ It was tested new construction of the fuel assemblies and control protection rods made from new structural materials.

Beloyarsk NPP (units 3) BN-600 past, today and future

Commissioning year – 1980

Real parameters up to 1986

- ✓ Burn-up 7,2 % H.M.
- ✓ Damage Dose 44 dpa
- ✓ Cycle length 200 - 300 eff. days

Fuel construction materials

- ✓ Pin cladding EI-847
- ✓ Assembly cladding 16Cr11Ni3Mo

Designated service life – 2010

Real parameters up to 2013

- ✓ Burn-up 11 % H.M.
- ✓ Damage Dose 82 dpa
- ✓ Cycle length 560 - 720 eff. days

Fuel construction materials

- ✓ Pin cladding ShC-68
- ✓ Assembly cladding EP-450

Experimental works last year.
Main following programs

- ✓ Experimental validation of the irreplaceable equipments working life.
- ✓ Reliability of the in-core equipments operation, including fuel assemblies and control protection rods.
- ✓ Increase design burn-up (increase design burn-up is planed to achieve due to improvement material properties pin cladding steel (for example forming, mechanical properties, corrosion resistance etc.).

Experimental works. Fuel burn-up increase

- Pilot phase of the unit operation with increase cycle length.
- Increase lifetime of the emergency protection rod.
- Irradiation of the fuel assemblies with different steels samples.
- Irradiation of the fuel assemblies with pins made from new steel.
- Irradiation of the MOX-fuel assemblies.

Experimental works. Future plan

Future parameters I phase
- ✓ Burn-up 11,7 % H.M.
- ✓ Damage Dose 87 dpa
- ✓ Cycle length
  596 - 756 eff. days

Fuel construction materials
- ✓ Pin cladding ShC-68
- ✓ Assembly cladding EP-450

Future parameters II phase
- ✓ Burn-up 15 % H.M.
- ✓ Damage Dose 110 dpa
- ✓ Cycle length
  710 - 770 eff. days

Fuel construction materials
- ✓ Pin cladding ?
- ✓ Assembly cladding EP-450

License procedure. Main principle

- ✓ All works, including fatigue tests of new types of fuel, are carried out at the unit 3 Beloyarsk nuclear power plants with the BN-600 reactor with the justification of the regulatory body.
- ✓ Justification procedure is standard for all power units and independent from the reactor types.
- ✓ The regulatory body and independent experts or technical support organizations, which can be involved in this work by the regulatory body, review SAR, operational manuals and other operator documents.

License procedure. Main principle

- ✓ Safety requirements (i.e. Federal rules and codes). The project and design documents shall meet safety requirements.
- ✓ The technical and organizational measures for safety guarantee shall meet well-known results of the research investigations or shall be experimental validate.

Safety criteria

- ✓ Construction materials behaviour in the fast breeder reactors substantially depend on radiation damage and thermal loads.
- ✓ Examination of construction materials after irradiation in the testing reactor often does not give answer about limiting characteristics, because irradiation conditions (neutron spectrum and fluence, thermal load etc.) of the testing reactors do not correspond with conditions of BN-600.
- ✓ Limiting characteristics (long-term strength, structural strength, combined strength, fatigue strength, irradiation-induced swelling, deformation) of the safety important elements are not known before lifetime testing.

Safety criteria

Operator

✓Special testing program
✓Describe and justify every
✓test steps
✓Based on experimental and expected data

Regulatory body

Safety review:
✓Previous experimental data
✓Federal standards and codes' requirements
✓Independent expert experience

Program implementation ⟹ Program results

Safety criteria.
Main equipments metal inspection

- ✓ The requirements for standard inspection program (procedure, rules) of the equipments and pipelines are defined in the PNAE G-7-008-89 (Rules for arrangement and safe operation of equipment and piping of nuclear power installations. Moscow, 1989).
- ✓ It shall be use destructive and non-destructive methods.

Safety criteria.
Main equipments metal inspection

- ✓ Destructive inspection of the metal and welds mechanical properties is implemented by testing of specimens installed in equipment or cut out (e.g. from the pipelines) according to requirements of the design documentation.
- ✓ Non-destructive inspection of main elements and pipelines shall be fulfilled periodically, and not later than 30000 hours of operation after the previous periodical inspection according to standard inspection program (procedure, rules). Inspection of the minor elements and pipelines important for safety – in each 45000 hours of operation after the previous periodical inspection.

Safety criteria.
Main equipments metal inspection

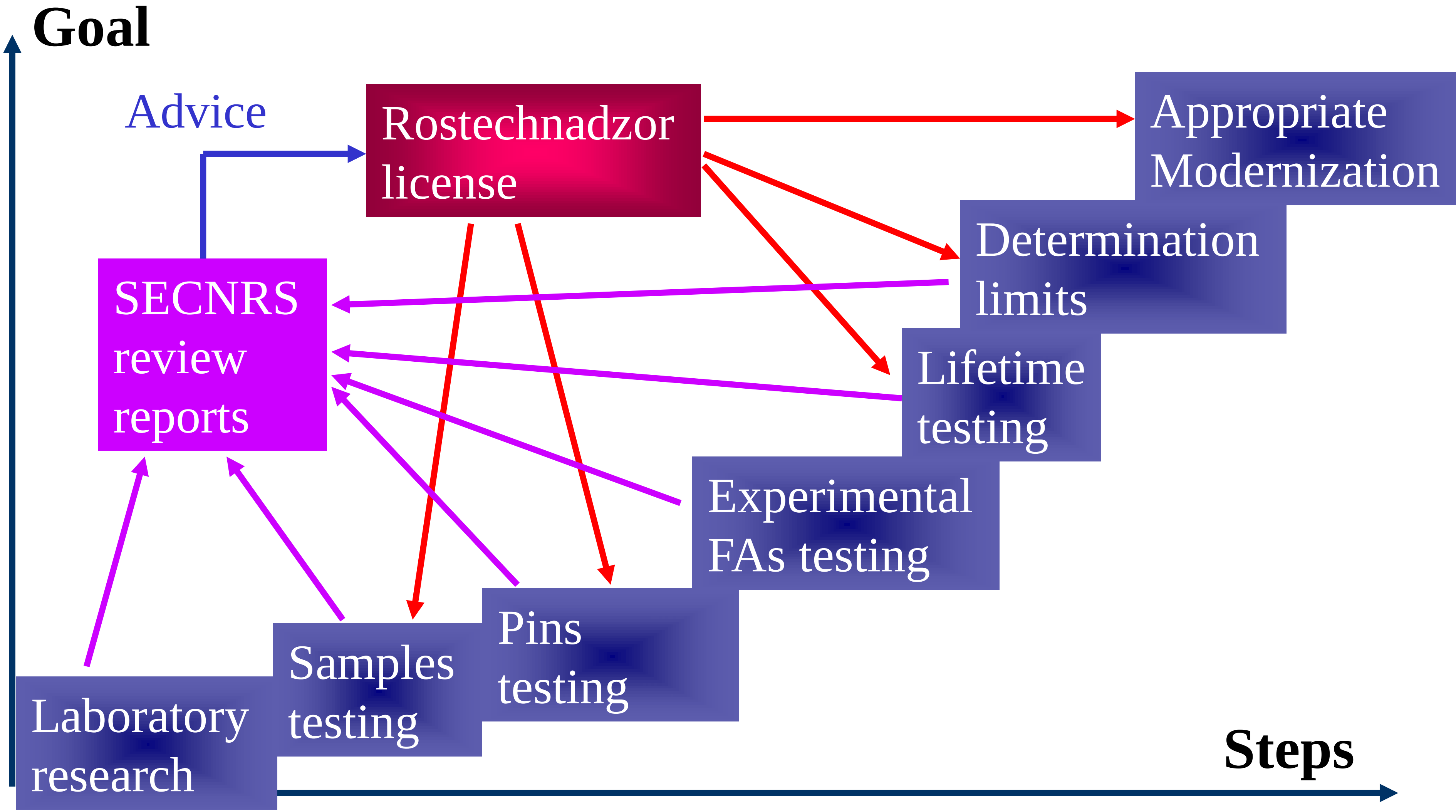
The specimens for destructive inspection are used for control of:

- ✓ change of mechanical properties (yield point, resistance to time, relative lengthening, relative narrowing);
- ✓ brittle fracture resistance properties (critical brittleness temperature, fracture toughness or critical opening of a rupture);
- ✓ properties of total and local corrosion (including pit corrosion, stress corrosion and intergranular corrosion).

Safety criteria.
Main equipments metal inspection

- ✓ The appropriate remote devices shall be provided for inspection of equipment in places where it can not be carried out by the standard devices due to radiation level or equipment layout.
- ✓ In case when reference specimens did not place operator shall carry out irradiation of the construction material specimens into such place of the core that irradiation conditions corresponded with operational conditions in-core elements.

Safety criteria. Fuel and control rods



Safety criteria. Fuel and control rods

The requirements are defined in the

- ✓ OPB-88/97 – General regulations on ensuring safety of nuclear power plants (PNAE G-01-011-97). Moscow, 1997;
- ✓ NP-082-07 – Nuclear safety rules for reactor installations of nuclear power plants. Moscow 2007
- ✓ TS TOB AS-85 – Standard Content of Technical Safety Justification of Nuclear Power Plants (PNAE G-1-001-85). Moscow, 1985

Safety criteria. Fuel and control rods

- To requires that technical and administrative decisions made for ensuring NPP safety shall be well proven by the previous experience or tests, investigations, operating experience of prototypes and shall meet requirements of regulatory documents.
- Such approach shall be applied not only in development of equipment and design of the NPP but also in manufacture of equipment, construction and operation of the NPP, its backfitting and reconditioning of its systems (elements).

Safety criteria. Fuel and control rods

- ✓ Improvement of control and protection system and other safety important systems, a required scope of bench and in-pile tests shall be carried out. And operator shall demonstrate to prove the safety criteria.
- ✓ It shall be determined and justified operational limits and conditions, safe operation limits and conditions and design limits established for design basis accidents.
- ✓ Codes and methodologies shall be verified and certified in accordance with the established procedures.

Safety criteria. Fuel and control rods

- ✓ It shall be demonstrated that the maximum design fuel damage limit established for design basis accidents with the severest consequences is not exceeded. The RI designs shall establish design fuel damage limits for other design basis accidents; their values shall be less than the maximum design fuel damage limit.

maximum design fuel damage limit :

- ✓ fuel rod cladding temperature – 900oC;
- ✓ fuel temperature – 2300^{o}C;
- ✓ volume swelling of FR cladding – 15%.

Safety criteria. Fuel and control rods

- ✓ Void effect in sodium coolant during normal operation and operational events, including design basis accidents is excluded.
- ✓ The core and its components' (including fuel rods and fuel assemblies) design and implementation during normal operation and operational events, including design basis accidents shall ensure fuel damage limits not exceed taken into account different factors to degrade mechanical properties of the core structural materials and integrity of the pin cladding.

Safety criteria. Fuel and control rods

- ✓ It shall be fulfilled substantiation for the conditions of normal operation, abnormal operation, and accidents and it shall take into account increase of the loads connected with failures of other systems.
- ✓ Such characteristics as mechanical, thermal-hydraulic neutronic, physicochemical, strength, etc. and reliability features shall be substantiated for each state of system operation, including failures of other systems.

In the conclusion it is necessary to note that accident-free operation of BN-600 confirms an approach to license support of the BN-600 operation used by the regulatory body now.

Thank you for your attantion