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Project margins of advanced reactor design VVER-500

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Introduction

Project criteria of advanced reactor design VVER-500 in design conditions are compared with the requirements of the Russian regulatory guides [1],[2],[3] in this presentation.

Normal operation limits, safe operation limits for main anticipated operational occurrences and design limits accepted for design basis accidents are considered as described in the preliminary safety report.

1. Acceptance criteria for of fuel cladding damage as required in the Russian regulatory guides

In accordance with [2], operating limits of fuel cladding damage including:

- 0.2% of fuel rods with the flaws of gas leakiness type and

- 0.02% of fuel rods with direct contact of nuclear fuel with coolant,

should not be exceeded.

In anticipated operational occurrences, safe operation limits including:

- 1% of fuel rods with the flaws of gas leakiness type and
- 0.1% of fuel rods with direct contact of nuclear fuel with coolant,

should not be exceeded.

For design basis accidents maximum design limits corresponding:
- fuel rod cladding temperature being equal 1200 oC

- fuel rod cladding local oxidation depth being equal 18% of initial cladding thickness

- reacted zirconium mass fraction being equal 1% of initial fuel rod cladding mass

should not be exceeded.

In addition, the threshold fuel rod destruction power generation should not be exceeded and fuel melting should be excluded in design basis accidents associated with a rapid positive reactivity insertion.

2. Fulfillment of design criteria in the design VVER-500 for anticipated operational occurrences and their list

2.1 The information on fulfillment of the basic design criteria in the design VVER-500 for anticipated operational occurrences is given below. The given data show that these criteria are more severe than the regulatory criteria shown in section 1.

2.1.2 The heat exchange crisis in the core is excluded. DNBR with 26,2% error is more than 1,0. Fulfillment of this condition provides reliable fuel rod cooling and no more than 0.1% of fuel rods with the flaws of gas leakiness type and 0.01% of fuel rods with direct contact of nuclear fuel with coolant (which is more severe than in section 1).

2.1.3 Maximum fuel temperature in any point of the core is less than melting temperature.

2.2 Below, a list of main groups and names of conditions which are considered in the design in a category of anticipated operational occurrences is presented.

2.2.1 Reactivity-induced occurrences
- Uncontrolled withdrawal of a control rod bank
- Inadvertent drop of fuel assembly

2.2.2 Occurrences with loss of secondary coolant
- Inadvertent opening of the steam dump valve or safety valve of SG with subsequent failure to close

2.2.3 Occurrences with reduction of the primary coolant flow rate
- Loss of power to all or several RCPs
- Loss of normal unit electric power supply

2.2.4 Conditions with variation of turbo-generator load and of feed water flow rate
- Turbo-generator load drop
- Loss of feed water supply
- Increase of turbo-generator load

2.2.5 Abnormal fuel assembly manipulations
- Erroneous loading of a fuel assembly into the core and its operation

3. Fulfillment of design criteria in the design VVER-500 for design basis accident and their list

3.1 The information on fulfillment of the basic design criteria in the design VVER-500 for design basis accident is given below. The given data show that these criteria are more severe than the regulatory criteria shown in section 1.

3.1.1 Primary and secondary pressure is maintained under 115% of design value taking into account possible transients (in accordance with [3])

3.1.2 Maximum fuel cladding temperature does not exceed 700 C. The increase above normal value occurs no more than 150 s. As these criteria are fulfilled fuel cladding destruction does not take place. Flow area constriction in the fuel assembly does not take place either.

3.1.3 Maximum fuel temperature in any point of the core is less than melting temperature.

3.1.4 The absence of fuel destruction in accidents induced by a rapid insertion of reactivity is provided if maximum UO2 enthalpy does not exceed 830 kJ/kg or radially averaged UO2 enthalpy does not exceed 386 kJ/kg. These values are determined on a basis of experimental data on fuel behaviour in conditions of impulse power increase. In the accidents below these values of enthalpy are not exceeded.

3.2 Below, a list of main groups and names of conditions which are considered in the design in a category of design basis accidents is presented.

3.2.1. Reactivity-induced accidents

- Ejection of a control rod as a result of break of the control rod drive casing

- Startup of an inactive reactor coolant loop

3.2.2 Accidents with loss of primary coolant

- Inadvertent opening and failure of the pressurizer safety valve to close

- Inadvertent opening of the primary circuit emergency

blowdown valve and its failure to close

- Small leaks with loss of coolant as a result of postulated breaks of the primary pipelines of diameter less than 100 mm

- Large leak with loss of coolant as a result of postulated break of the primary pipelines of diameter more than 100 mm and up to diameter of main coolant pipeline.

3.2.3 Accidents with loss of secondary coolant
- Break of SG feed water line

- Spectrum of steamline breaks within and outside the boundaries of the containment (including the case with simultaneous break of one heat exchange tube in the SG with damaged steamline)

3.2.4 Accidents with reduction of the primary coolant flow rate
- Instantaneous seizure or break of one RCP shaft

3.2.5 Primary to secondary leaks
- SG tube rupture

- SG primary collector leak with 100mm equivavent diameter

- SG primary collector 790 mm full diameter leak

3.2.6 Accident situations during manipulation with fuel assemblies
- Erroneous loading of fuel assemblies into the core and its operation

- Drop of fuel assembly under refuelling

- Drop of loads into the reactor and into the spent fuel storage

4. Conclusion

It is shown that the basic design criteria in the design VVER-600 for the anticipated operational occurrences and for the design basis accidents are more severe than required in accordance with [1], [2]. This provides certain margins from the viewpoint of safety.

References

[1] General safety regulations for nuclear power plants (OPB-88), Gosatomnadzor, USSR, Moscow, Energoatomizdat, 1990.

[2] Nuclear safety rules for reactors of nuclear power plants, PBYA RU AS-89, Moscow, 1990.

[3] Guidelines for construction and safe operation of equipment and pipelines of nuclear power plants, PN AE G-7-008-89, Gosatomnadzor USSR, Moscow, Energoatomnadzor, 1990