Method and Result of Experiment for Support of Technical Solutions in The Field of Perfection of A Nuclear Fuel Cycle for Future PWR Reactors

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The paper presents the basics of approach of planning and carrying out of experiments to validate safety PWR reactors of the future when accepting technical solutions concerning using of improved fuel rods in fuel assembly.

Basic principles and criteria used for the validation of technical solutions and developments in improving of nuclear fuel cycle of PWR reactors of the future are presented from the point of safety of future operation of modified fuel rods. We explore the questions of safety operation of PWR reactors with fuel assemblies, containing fuel rods with different length of fuel.

The paper discusses the ways of solving of important tasks of critical facility experiments conducting for verification of new technical solutions in the sphere of PWR nuclear fuel cycle improvement on the base of international standards ISO 2000:9000 and functional safety recommendations of IEC (International Electromechanical Commission).

New Federal laws of Russian Federation define the main principle for demands to NPP and any supplier of nuclear techniques. The principle is "quantity indicators of risk should not exceed comprehensible social size of the established indicators of safety for any moment of operation of NPP". On the other hand the second principle should be applied to extraction of the greatest benefit from operation of the equipment, systems or the NPP as whole: "The long operation and full commercial use of resource and service properties of the equipment, systems and the NPP as a whole". Realization of this principle assumes development and introduction of new technical solutions for a validation of guarantees of safety of the future operation of NPP or it separate components.

Solving the practical problems of a validation of safety use of fuel rods with the increased length of a fuel column in fuel assembly in nuclear reactors of the future, we should choose new strategies and programs of verification experiments on the base of the analysis of guarantees quality representation of safety, reliability, efficiency and benefit of operation of the NPP. From here there is a new problem of construction of the system of statement and carrying out of experiments in substantiations of functional safety of PWR reactors of the future. In view of world tendencies of development of production and services the decision of the problem is being carried out in the environment of constantly improved quality control system (QCS) of the processes of the whole life cycle of nuclear installations constructed under the Russian projects. The QSC bases on the principles of a quality management of international standards ISO of a series 9000:2000, namely orientation to a consumer lay; system approach to management; the process approach for carrying out verification researches; the decision-making based on saved up experience, knowledge base and database; leadership of the head; constant improvement of QSC, etc.

Nowadays the validation of safety is based on calculation forecasts. According to calculation forecasts the distribution of power field in WWER-1000 fuel assemblies close to fuel assemblies with lengthened fuel column fuel rods is defined basically by the influence of compensatory volumes of not advanced fuel rods. Such situation arises in the beginning of a stage of introduction of new type fuel assemblies, when their amount in core is insignificant and regular fuel assemblies surround them. An experimental research of a core of PWR reactors of the future in the situation, when fuel loading will include fuel assemblies with various length of a fuel column, is a necessary condition of verification of calculation forecasts. The primary goal of such researches is a modeling of the situations arising at the beginning and the end of a cycle of introduction of advanced fuel assemblies and definition of mutual influence of different type fuel assemblies on a power field distribution.

At carrying out of experiments the typical algorithm shown on fig. 1 was used.

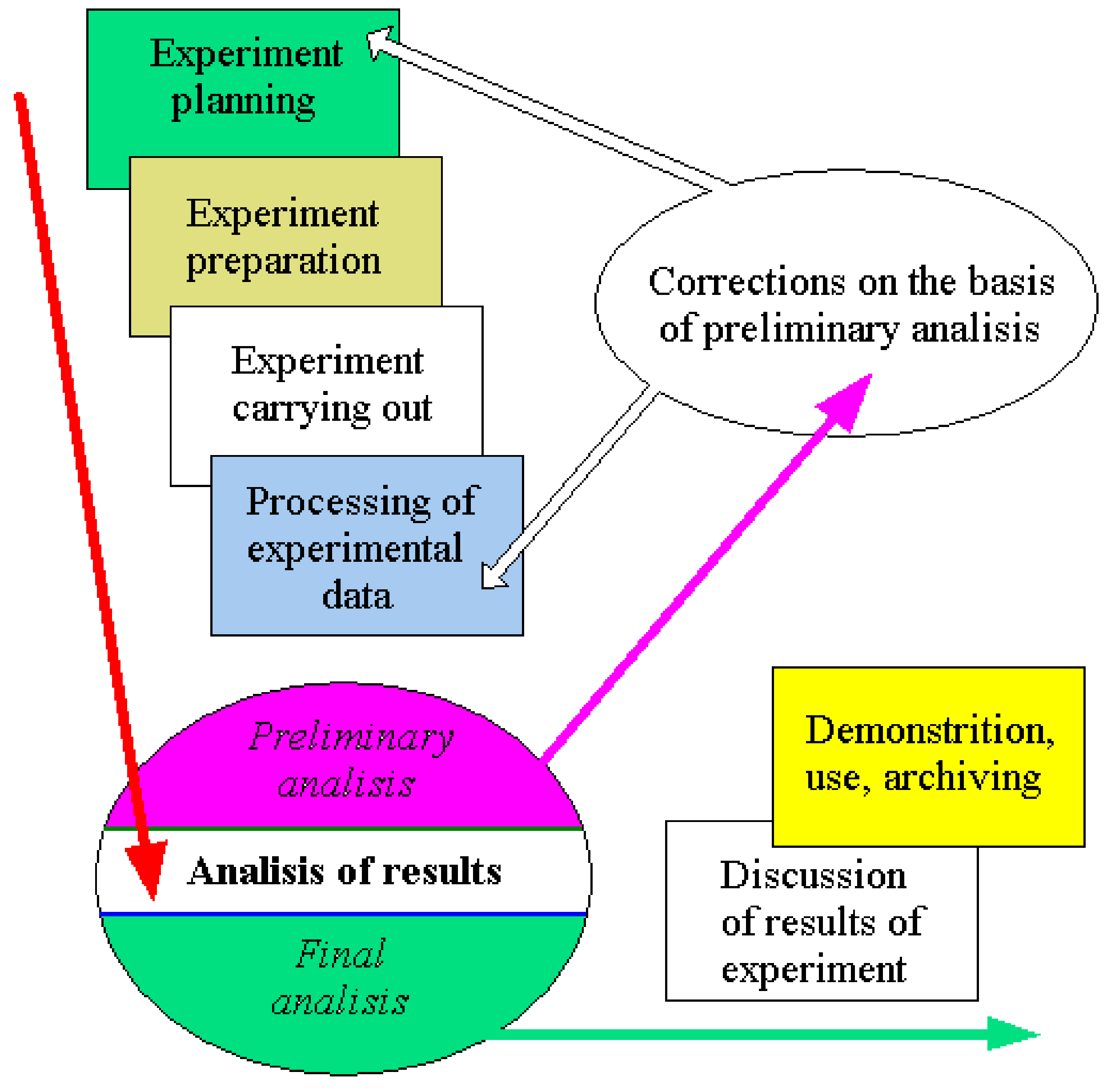

FIG. 1.Typical algorithm of carrying out of experiment.

To explore different type fuel assembly's core, the internal part (331 cells, WWER-1000 fuel assembly model) was lifted on some height in comparison with associate's fuel rods. The core views are presented on fig.2-3.

The moderator was light water without boron acid. It made possible to explore maximum effects. In order to increase critical moderator level fuel rods with 2,4% enrichment by U-235 were used.

FIG. 2. The bottom of core (fuel rods of peripheral part are taken from sector of symmetry 60 deg.).

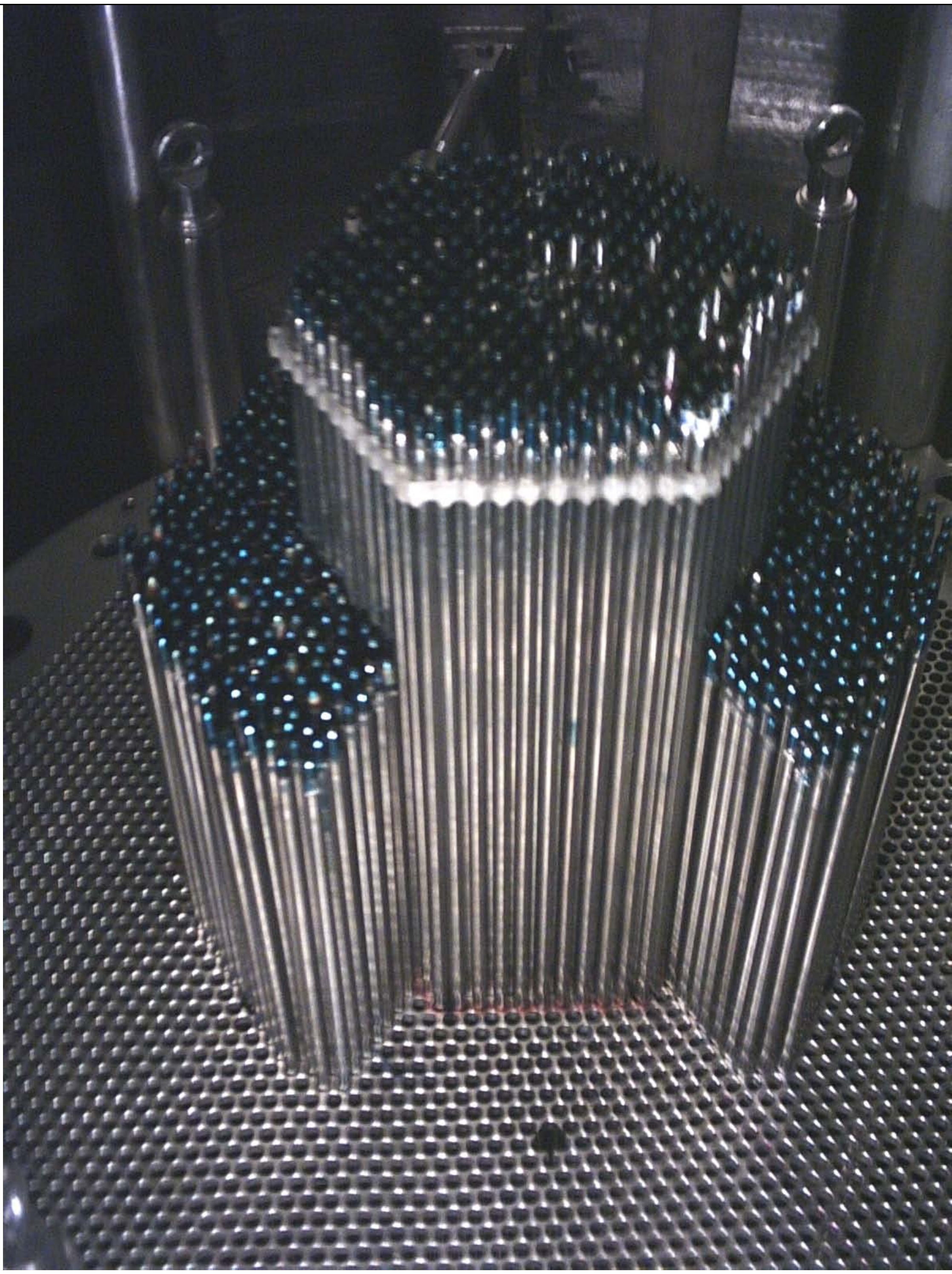

FIG. 3. The top of core (fuel rods of peripheral part are taken from sector of symmetry 60 deg.).

Relative axial distribution of power field has been measured in fuel rods, located in the middle of the first sequence, surrounding WWER-1000 fuel assembly model, and on edge of some. The results of the experiment are presented on fig.4. The fuel bottom is bottom of fuel of fuel rods, surrounding WWER-1000 fuel assembly model.

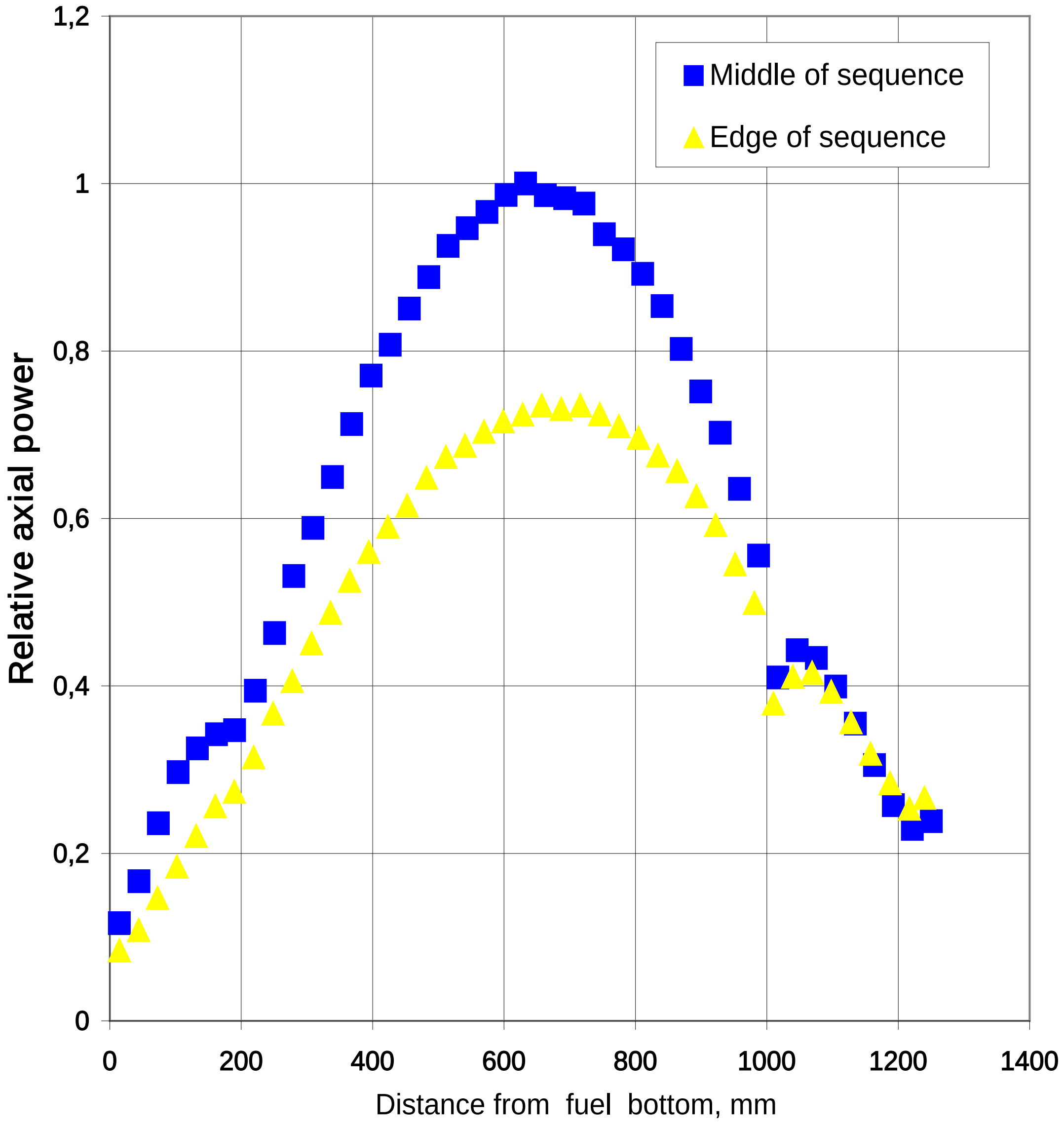

FIG. 4. Relative axial power distribution in fuel rods, located in the middle of the first sequence, surrounding WWER-1000 fuel assembly model, and on edge of some.

Relative axial power distribution was measured in fuel rods, located in the middle of the last sequence of WWER-1000 fuel assembly model, and on edge of some. The results of the experiment are presented on fig.5.

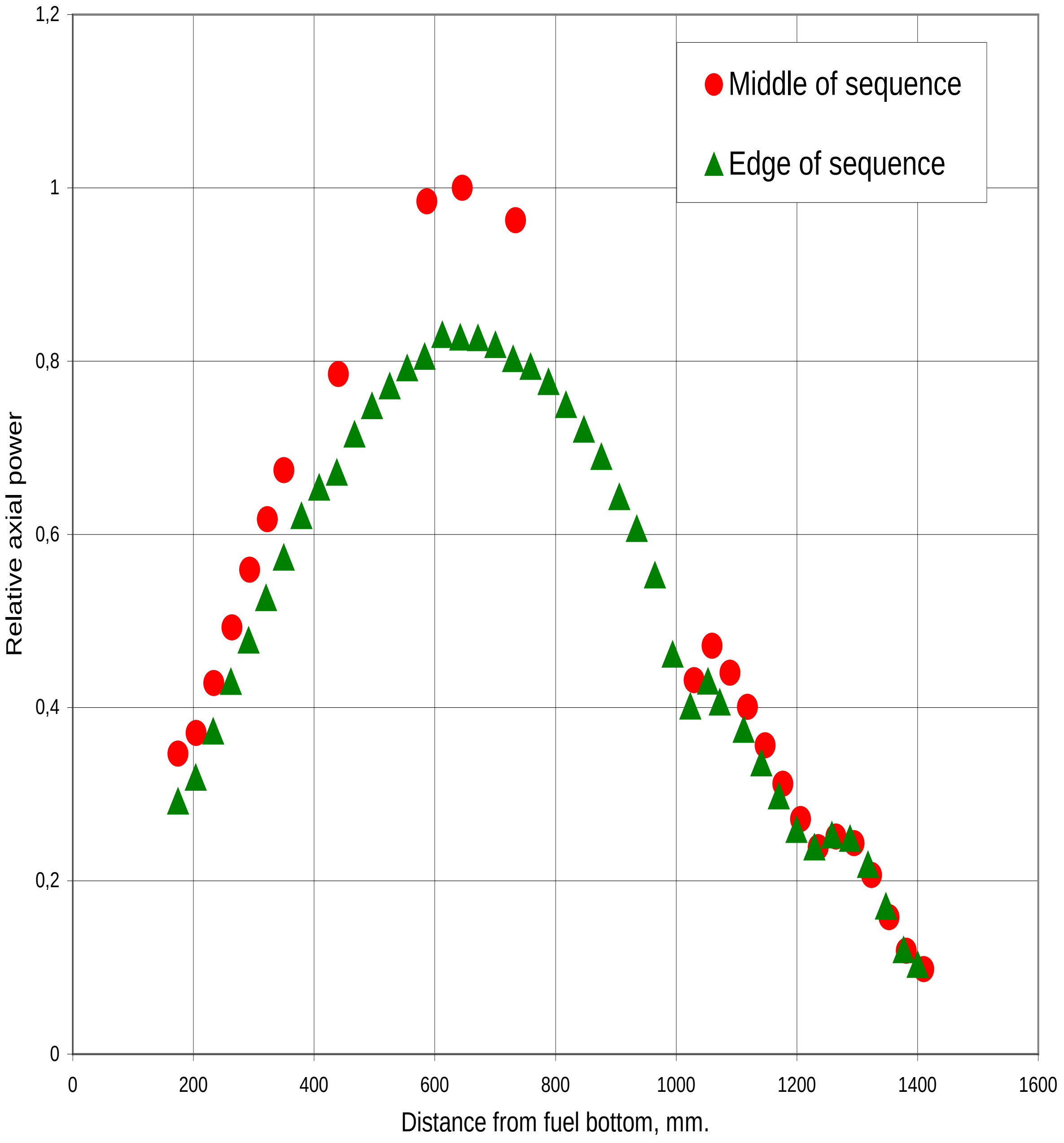

FIG. 5. Relative axial power distribution in fuel rods, located in the middle of the last sequence of WWER-1000 fuel assembly model, and on edge of some.

Comparison of relative axial power distribution in fuel rods, located in the middle of the pre-last and last sequences of WWER-1000 fuel assembly model is presented on fig.6.

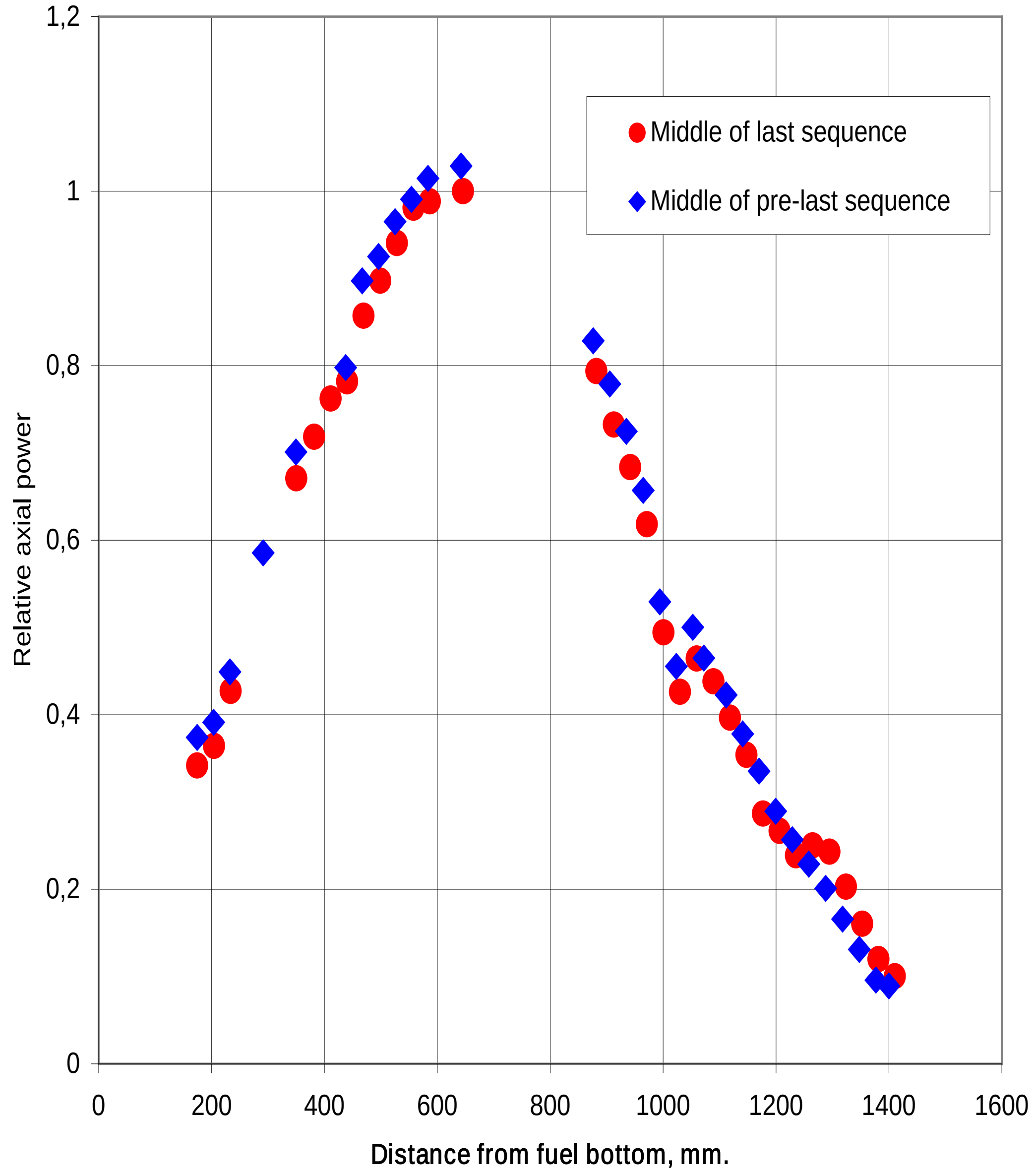

FIG. 6. Comparison of relative axial power distribution in fuel rods, located in the middle of the pre-last and last sequences of WWER-1000 fuel assembly model.

To decrease moderator density under the WWER-1000 fuel assembly model aluminum rods ∅8×143 mm were used. They were placed in the cells under WWER-1000 fuel assembly model fuel rods.

Relative axial distribution of power field has been measured in fuel rods, located in the middle of the first and second sequences, surrounding WWER-1000 fuel assembly model. The results of the experiment are presented on fig.7.

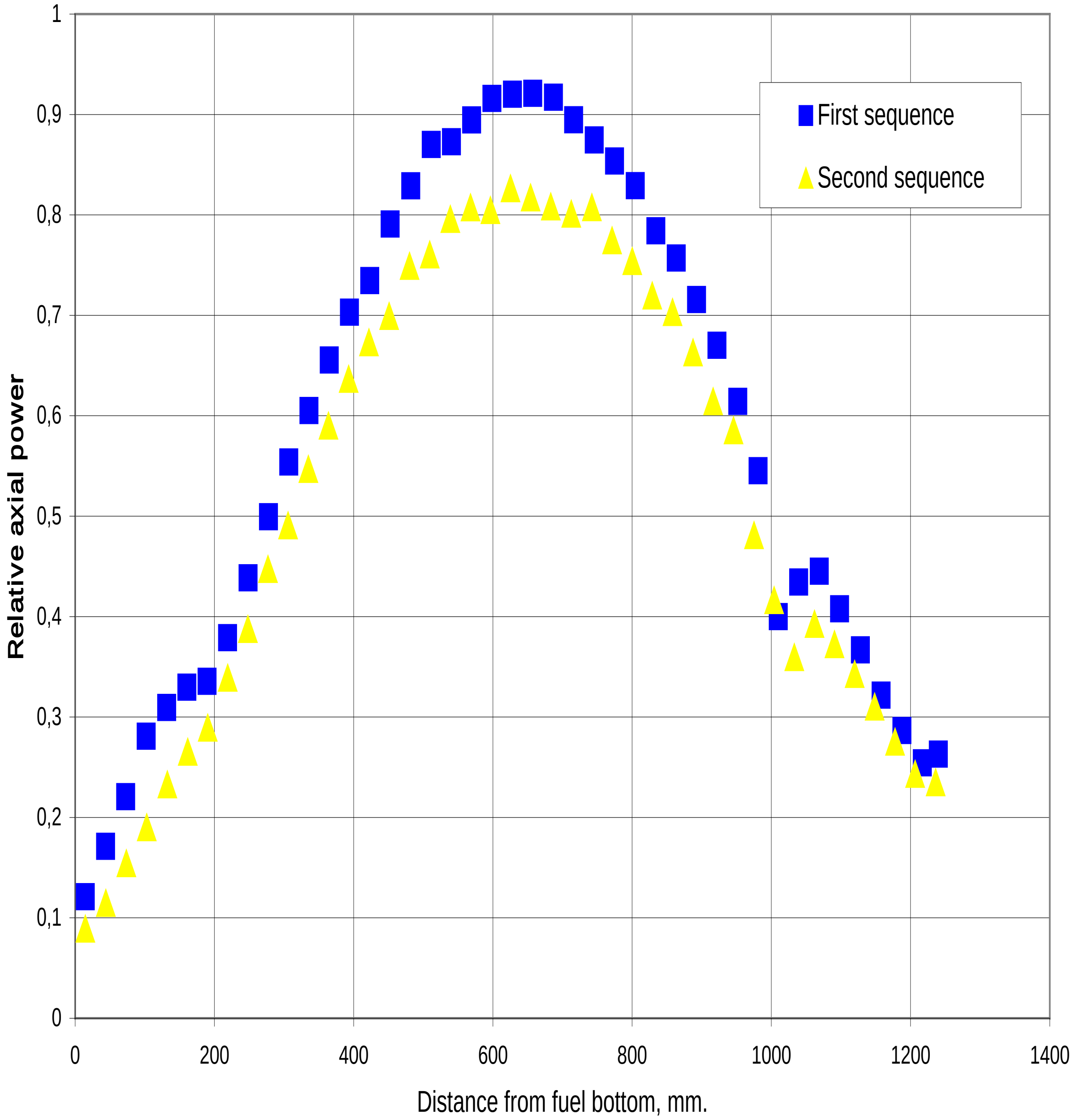

FIG. 7. Relative axial distribution of power field in fuel rods, located in the middle of the first sequence, surrounding WWER-1000 fuel assembly model, and on edge of some.

Relative axial power distribution was measured in fuel rod, located in the middle of the last sequence of WWER-1000 fuel assembly model. The results of the experiment are presented on fig.8.

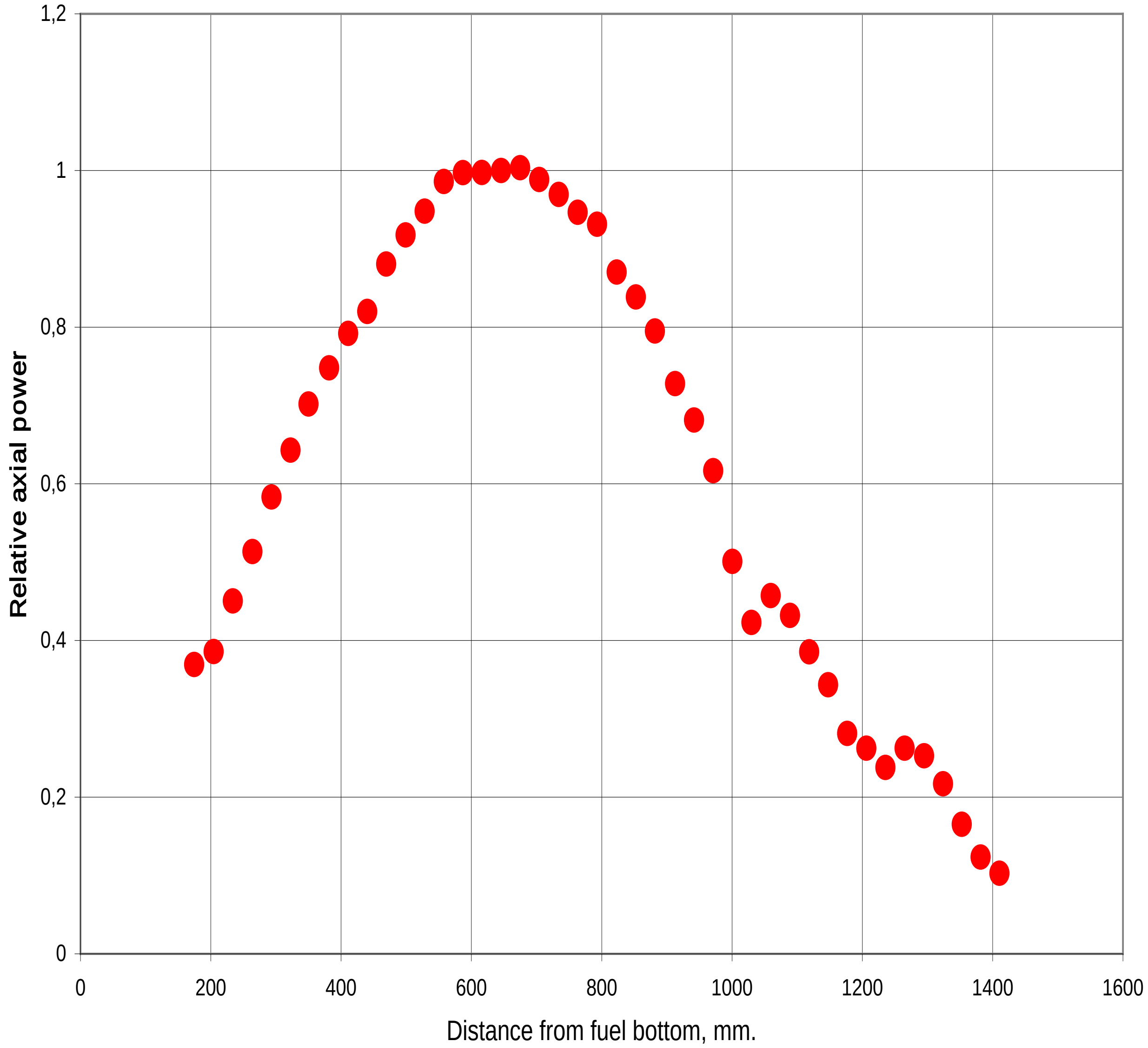

FIG. 8. Relative axial power distribution in fuel rod, located in the middle of the last sequence of WWER-1000 fuel assembly model.

Comparison of relative axial power distribution in fuel rods, located in the middle the last sequence of WWER-1000 fuel assembly model and in the middle of the first and the second sequences, surrounding WWER-1000 fuel assembly model, is presented on fig.9.

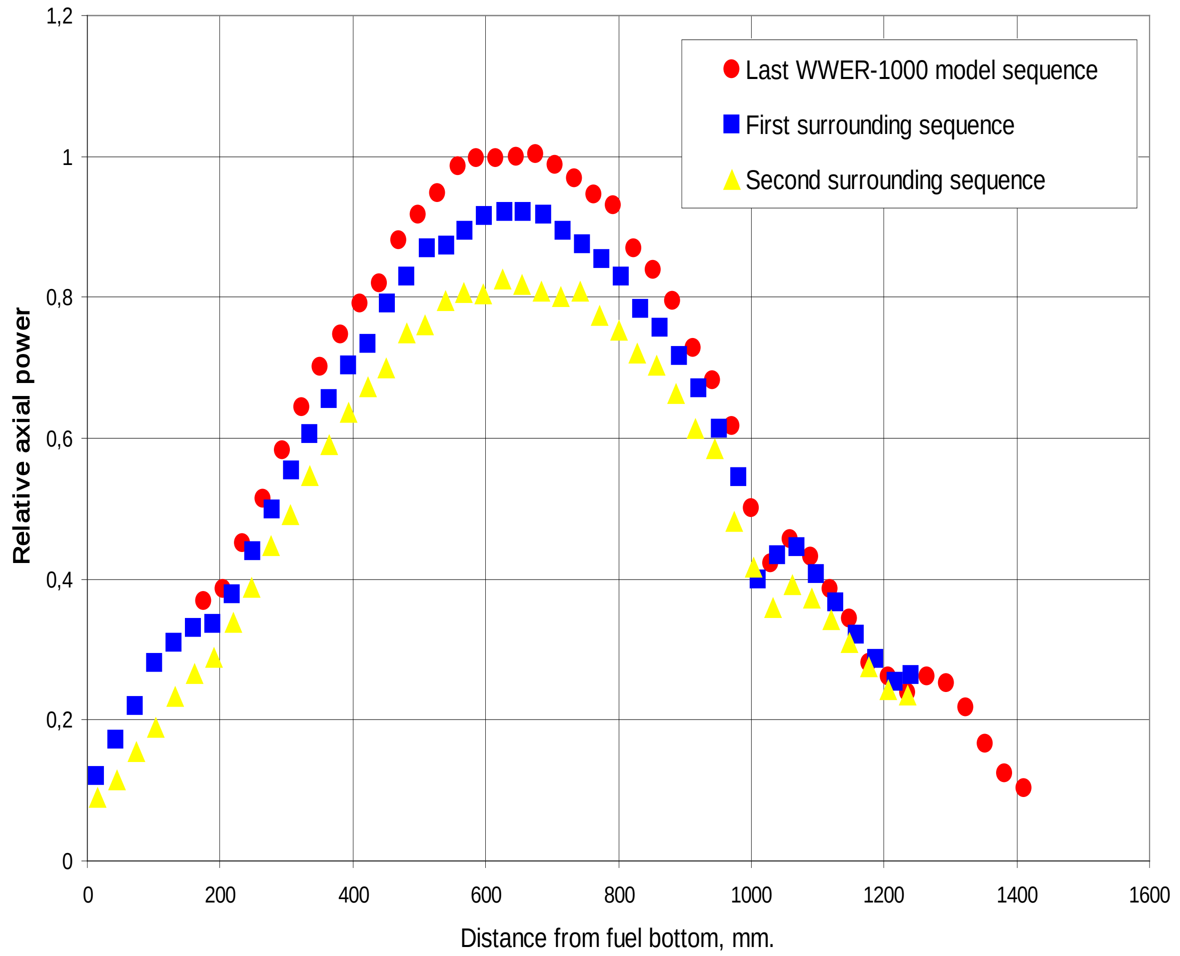

FIG. 9. Comparison of relative axial power distribution in fuel rods, located in the middle the last sequence of WWER-1000 fuel assembly model and in the middle of the first and the second sequences, surrounding WWER-1000 fuel assembly model.

Comparison of axial power distribution in fuel rod, located in the middle the first sequence, surrounding WWER-1000 fuel assembly model, for different moderator density under WWER-1000 fuel assembly model is presented on fig.10.

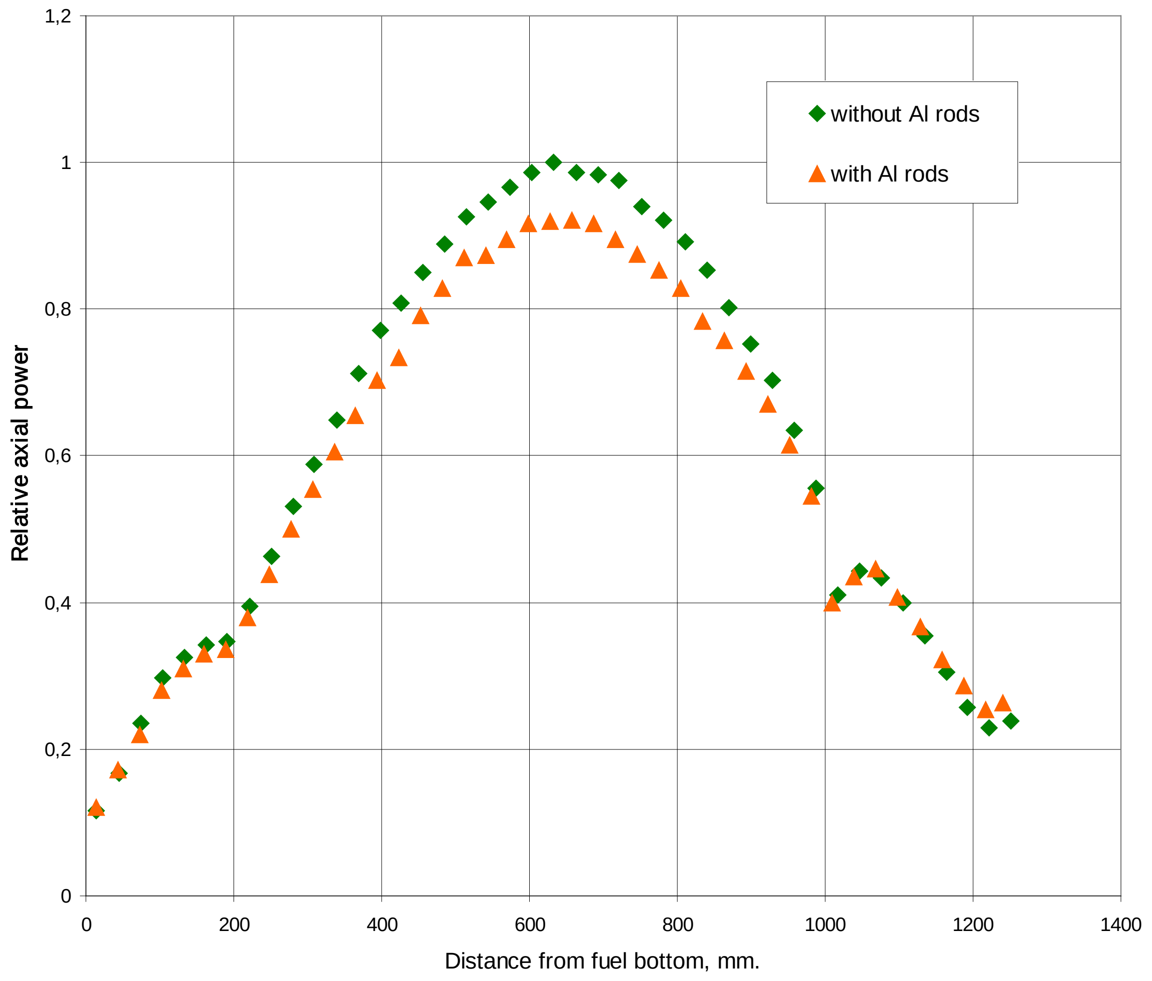

FIG. 10. Comparison of axial power distribution in fuel rod, located in the middle the first sequence, surrounding WWER-1000 fuel assembly model, for different moderator density under WWER-1000 fuel assembly model.

The lead experiments have shown, that the increase of axial distribution of a power field in fuel rods, surrounding WWER-1000 fuel assembly model, is observed. But this increase cannot affect the fuel rods operation safety of since it is insignificant and is in the field of where the power is approximately in 10 times less, than in the fuel rod center.