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RUSSIAN GRAPHITE NUCLEAR APPLICATION. HISTORY, STATE OF THE ART, FUTURE

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Abstract

Near 40 nuclear reactors based on graphite moderator were built in Russia during 50 years.

They are: RBMK, AMB, production reactors. Reactor graphites grades GR-220, GR-280, EGP-6, GR-94, GRP-2-125 were used for this reactors construction. Some grades of new graphites were developed on the Russian HTGR program such as GR-1 showing best radiation stability.

About 20 reactors were stopped due to exhaust of cladding resourses and/or metalwork structures and other reactor systems.

Production reactors (AI, AD, AV types) graphite claddings must to be dismounting but at the present time this work is in preliminary study stage. These reactors will not be demolished during 30 years.

The waste recovery program is developing now. There are two possible ways to reclaim graphite products:

- to born in special furnaces;
- to keep them in containers under special preserve compound.

At the same time very important to define the impurities in graphite claddings half-life in order to detrmine minimal period before its processing and conservation.

Near 40 uranium-fueled graphite moderated reactors of different types were built in Russia during 50 years. 20 reactors were shutdown.
As a rule, the graphite GR-220 and GR-280 are used as moderator in RBMK, AMB and production reactors.

The decommission problem of graphite reactors divides to two main ones: when reactor must be shutdown and how it will be decommissioned.
Our approaches to first problem are follow.

There are three criteria for evaluation the reliability of the channel reactor graphite stack:

- degradation of physical and mechanical properties of graphite as material;
- preservation of the graphite brick integrity;
- degradation of the graphite stack as a structure.

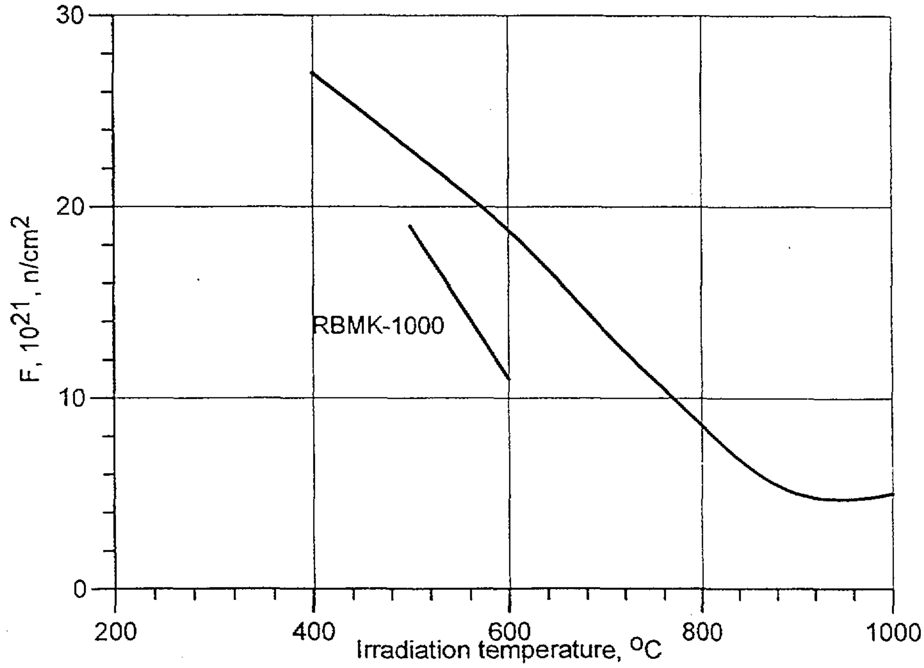

Fig. 1. GR-220/GR-280 critical neutron fluence vs. irradiation temperature and operation condition of RBMK-1000.

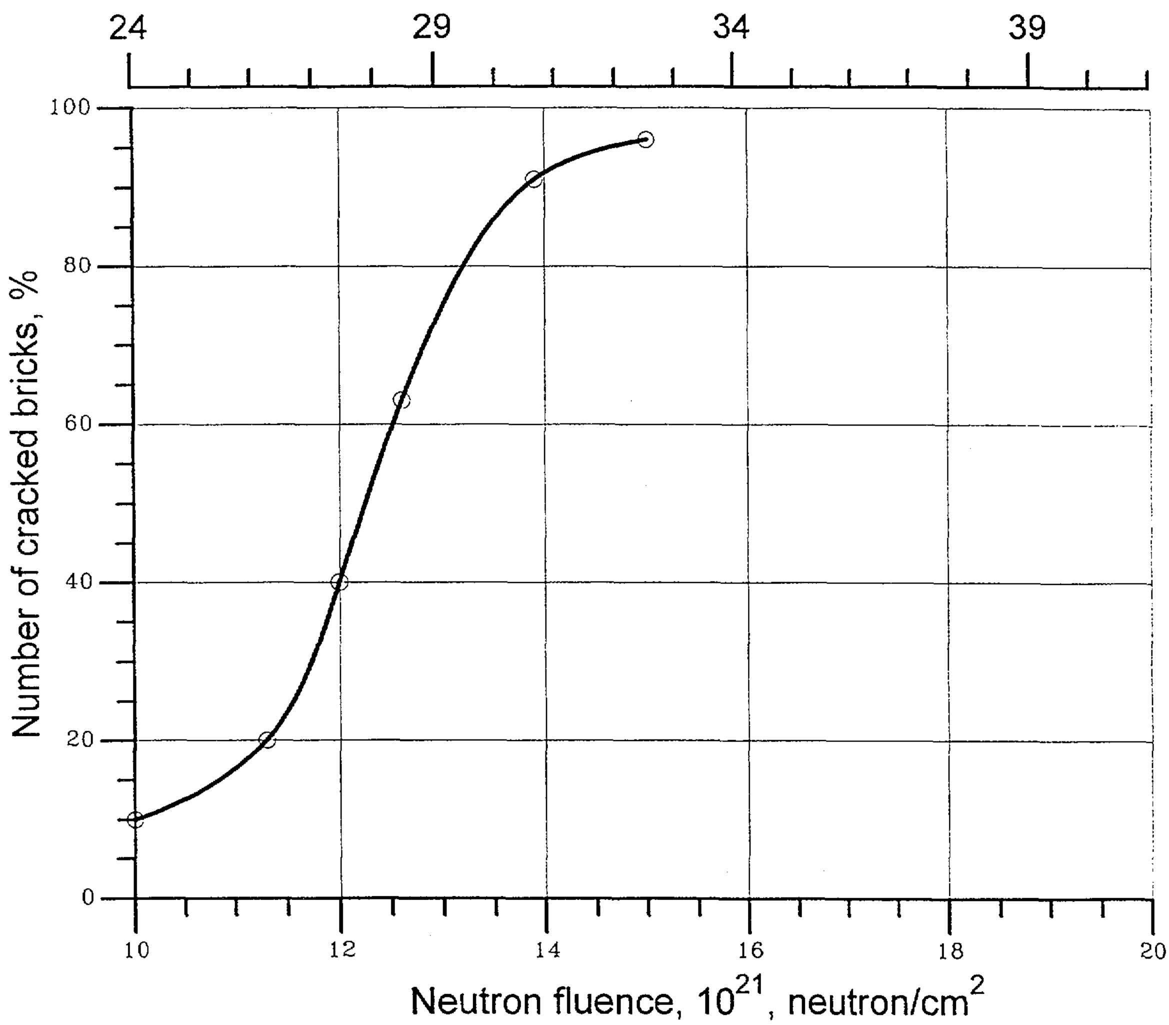

Fig. 2. The cracking of graphite bricks during reactor AV-3 operation.

As a criterion of graphite degradation, the critical fluence has been taken ([1]). For the temperatures characterized for existing Russian graphite reactor the critical fluence is that fluence, when the shrinkage of material is changing to swelling. In the most part of operating reactors the critical fluence will be not reached even after prolongation of design lifetime, see Fig.1.

The reactor stack consists of free standing columns, consisting of the bricks of square section. The fracture of graphite bricks does not bring to threat to the operational reliability of the stack as a whole.

In the long time operated reactors the swelling of inner brick layers cause the tensile stresses on external brick surface and subsequent cracking during temporary shutdown (for preventive maintenance) when the cladding cooling, see Fig.2.

The fracture of even most part of bricks in such core structure does not cause a disruption in the graphite stack functions as a moderator but the stack temperature arising that cause the increasing of graphite swelling rate. 5-7 years pass from the beginning of cracking to the beginning of change in configuration of the whole stack. This changes of stack configuration up to critical value of graphite column binding passed approx. 8 years. So, 15 years passed from the beginning of cracking to the reactor shutdown in consequence of the stack degradation, see Fig.3.

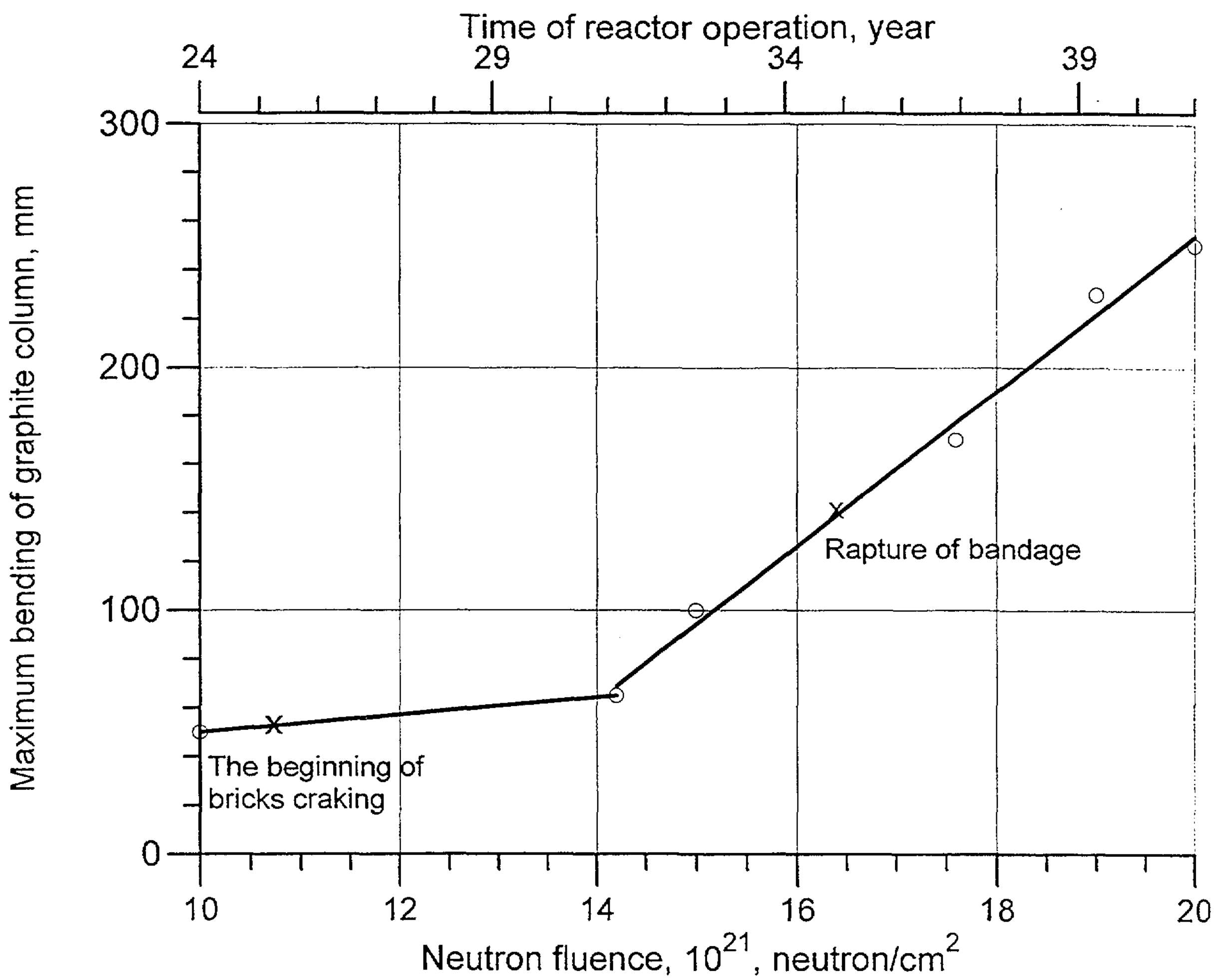

Fig.3. Maximum bending of graphite columns during AV-3 reactor operation.

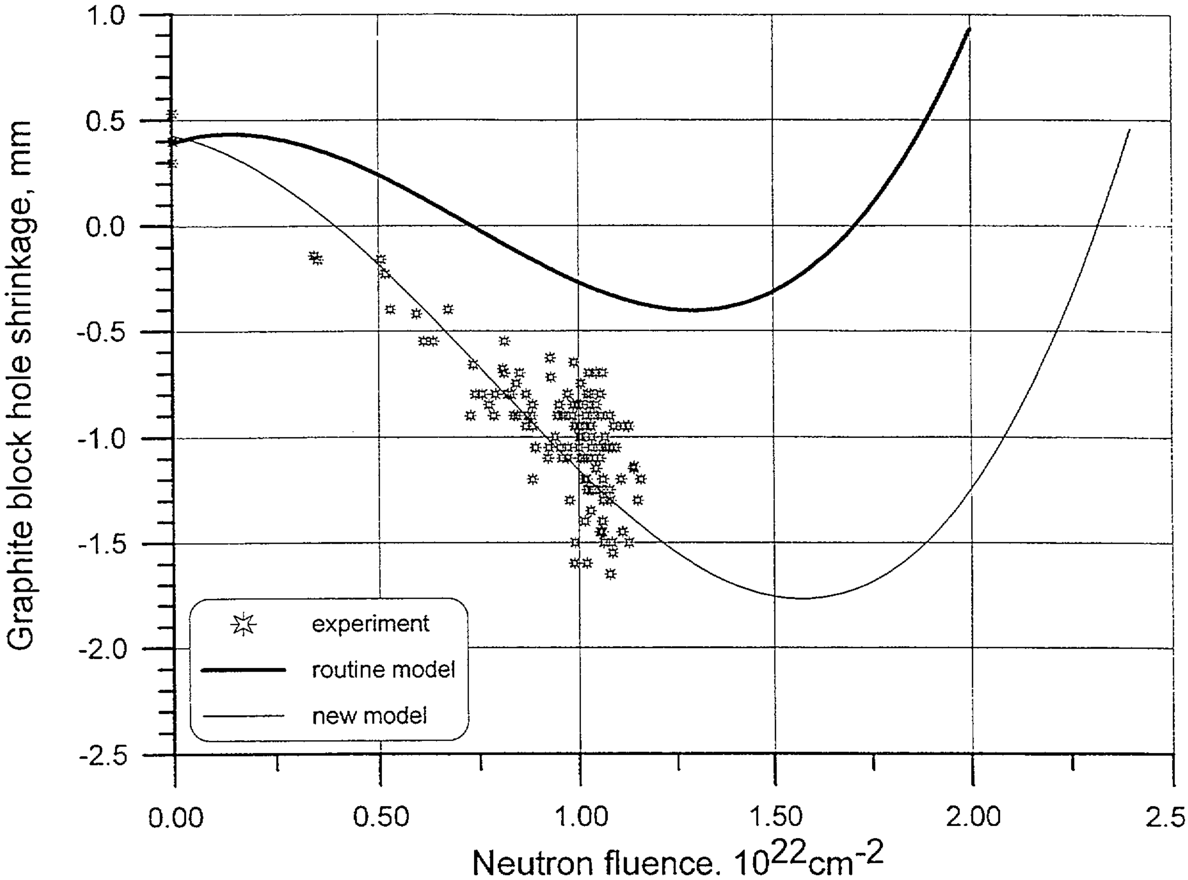

Fig.4. Changes of graphite block hole under irradiation. Leningrad NPP, Unit 2.

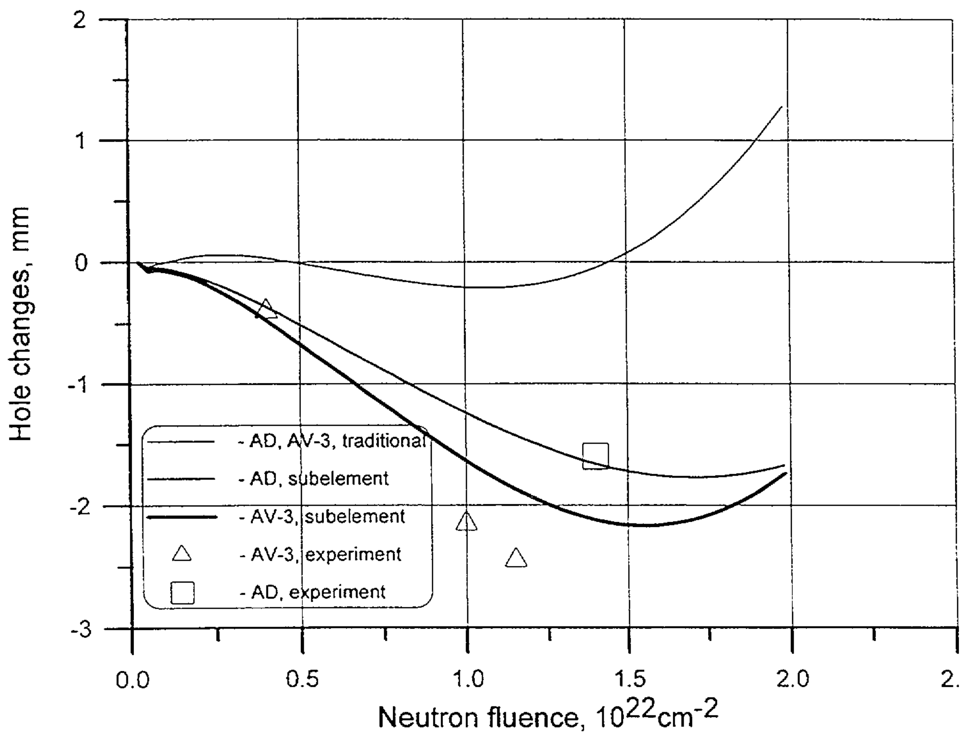

Fig.5. Changes of brick hole calculated on the base of traditional and subelement models and experimental data vs. neutron fluence.

What we will doing with long operating reactors graphite stack? It is necessary to define the condition of each graphite stacks for the operating its to the utmost. By the program we will take the probes (trepans) from the bricks, the whole graphite bricks from central part of core (RBMK), investigate its, including additional advanced irradiation in the test reactors, in order to determine the existing stack condition and its residual lifetime.

Other problem of this work is the calculation code revising. It is well-known that the traditional models and calculation codes cannot gives correct results of graphite bricks stress-strain conditions. That models are consider the graphite as solid continuos matter. And calculations gives the results differ from direct experiments.

On the base of electron microscopy investigations, making in our Institute from early 80-th, showing the mechanism of radiation damage of graphite [2], were made new calculation model for describing the existing processes in the structure of graphite under irradiation. The crystallites of graphite filler and binder, differed by sizes and radiation growth rates, are viewing as different subelements deformed and cracked by mutual interaction.

The verification of this model was made on the calculations of RBMKs and numerous production reactors stress-strain condition, displacement changes of brick holes and its rate. The results of RBMK-1000 graphite bricks shrinkage are presented on Fig.4.

In the Fig.5. the calculated brick hole changes made by traditional and subelement models and experimental data are shown.

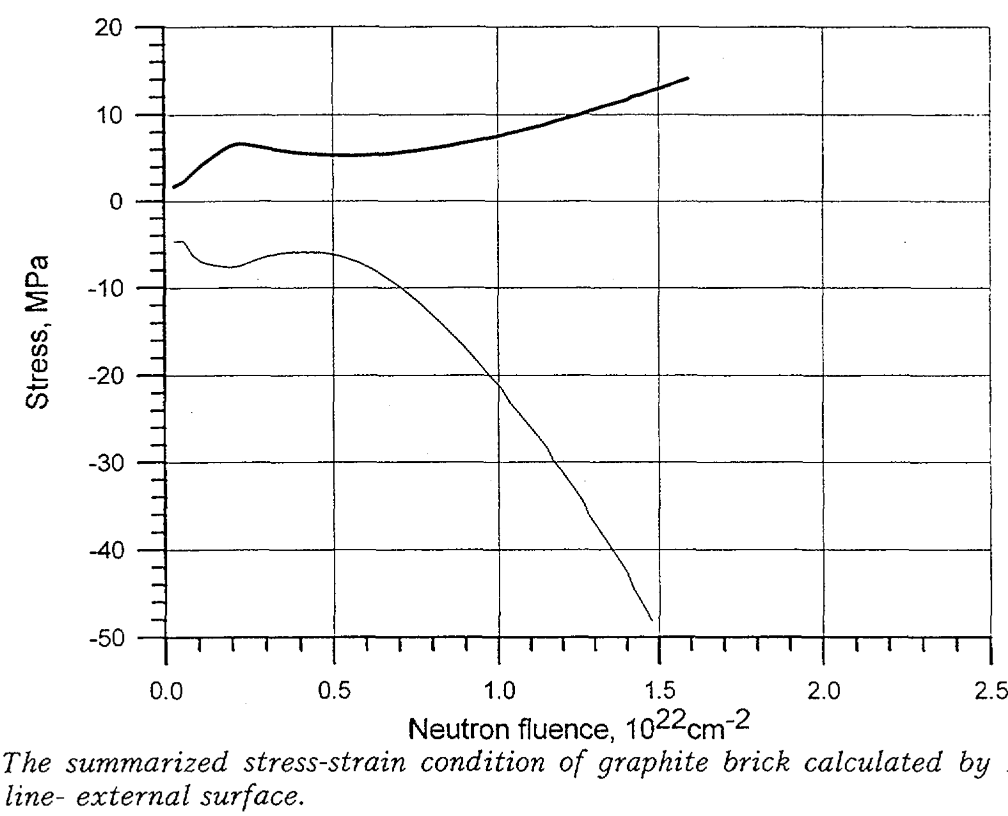

Fig.6. The summarized stress-strain condition of graphite brick calculated by F-model. Heavy line- external surface.

The results of stress-strain condition of AV-3 reactor graphite brick, shown in Fig.6 are successfully corresponding with experimental results of bricks cracking (see Fig.2.): after reaching neutron fluence of $1.2 \cdot 10^{22}$ cm^{-2} the stress reached the limit level (≈10 Mpa) and bricks begin cracking.

The problem of shutdown reactor decommissioning in the part of nuclear graphite is studied in package with all tasks on investigations of graphite as material, as stack and taking account with interactions it with fuel channels and helding bandages of cladding.
Generation of principles, criteria and technologies of RBMK graphite utilization are the main aims of such Russian program. Common quantity of graphite in builded RBMK is 30,000 tons from 50,000 tons of all Russian graphite reactors. By the program, in order to developing principles on safe handling with irradiated graphite will be working out the techniques of:

- definition of radioactivity, its distribution (C-14, fuel, fission fragments);
- investigation of graphite properties;
- technology of graphite bricks dismounting;
- technologies of chemical and physical influence on radioactive graphite (breaking, milling, cutting of layers with fuel, impregnation by conservants, burning of graphite etc.);
- technologies of storage.

Some of these technologies are developed.

The technologies of AMB-100 reactor will be developed on the first stage, then this technologies will be adapted to RBMK-1000.

The cladding of production reactors will not be dismounted during at least 30 years.

REFERENCES

1. Ya.Shtrombakh et al., J. Nucl. Mater., 225 (1995), pp.273-301.
2. Graphite moderator lifecycle behaviour, IAEA-TECHDOC-901, 1996, pp.79-90.