IMPLEMENTATION OF GIR2 PULSE NUCLEAR REACTOR FOR EDUCATION AND TRAINING OF UNIVERSITY STUDENTS

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ABSTRACT

GIR2 improved pulsed reactor, the successor to GIR, its design, power excursions and implementation for education and training of University students are discussed. The subjects of training course are presented.

INTRODUCTION

RFNC-VNIIEF offers a unique variety of research pulse nuclear reactors (PNR) designed to test various equipment for radiation resistance (Bosamykin et al., 1994). The LIU-10-GIR system involving a high-power pulse electron accelerator and a nuclear pulse reactor is used for investigation purposes (Bosamykin et al., 1995).

At present the problem is how to extend the use of existing PNR facilities. The implementation of such facilities as a relevant teaching aid is one way. Fast-neutron pulse nuclear reactors, with their compact and simple fuel core, corresponds with reasonable accuracy to simple physical models for students. The dynamic power variations peculiar to these reactors provide the students with better knowledge of nuclear reactor physics and operation.

Moreover PNR is a high-power neutron and gamma-quanta source. This makes it possible to carry out the training programs on propagation of radiations through various materials, radiative effects and radiation recording.

In 1995-1996 GIR2 was first used in the laboratory research course for the fourth -year students studying nuclear reactor physics at the Experimental Physics Department of the Technical University of Sarov who are prepared to become experts of VNIIEF Nuclear & Radiation Research Center. In the future the safety of NPR operation and criticality experimentation will depend to a great extent on the education level of the University graduates.

GIR2 REACTOR

The GIR2 fast-neutron pulse reactor, designed specially to operate in LIU-10-GIR system, has replaced the GIR reactor. The reactor core is made of uranium/9% molybdenum alloy. The 0.3 m diameter spherical core (Figure 1) is enclosed in 0.06 m thick dome-shaped neutron reflector. The reflector is made of a homogeneous cadmium oxide/polypropylene mixture increasing gamma output from the GIR2 facility and attenuating disturbances of the core from external devices. There is lateral hole 0.3 m in diameter in the reflector to take full advantage of the reactor’s capabilities as neutron radiation source.

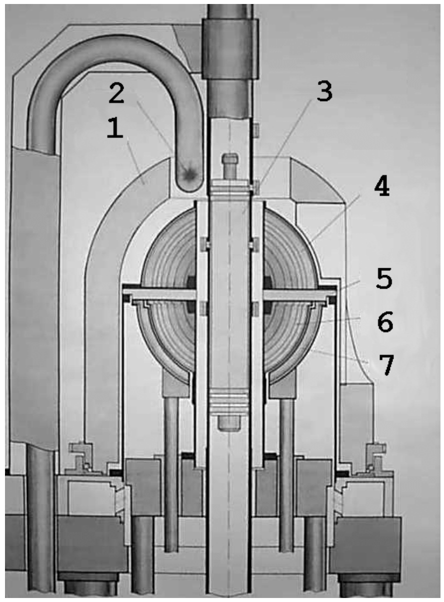

Figure 1 GIR2 Reactor Core Schematic: 1-reflector, 2-neutron source, 3-pulse unit, 4-upper unit, 5-diaphragm, 6-gross adjustment unit, 7-finer tuning unit.

The reactor core is composed of three fuel units. The fuel units comprise hemispheric uranium pieces enclosed in the sealed stainless steel jacket 0.002 m thick. The upper half reactor core is stationary fuel unit fitted to the steel diaphragm. The external uranium hemisphere of the upper unit is enriched to 36% in ^{235}U and the internal ones are enriched to 90%.

GIR2 power is controlled by two lower units moving relative to each other and the upper part. The inner part of the reactor core's lower half represents the gross reactivity adjustment unit (height of lifting is 0.1 m, efficiency is 18 k_{eff}., efficient portion of delayed neutrons is k_{eff} = 0.0067). It involves fuel pieces enriched to 90% in ^{235}U. The outer part of the reactor core's lower half composed of uranium hemispheres enriched to 36% and represents a finer tuning unit (height of lifting is 0.06 m, efficiency is 5 k_{eff}.). The outer low-enriched uranium pieces protect the reactor core regions bordering the reflector against overheating. When the control units are in the uppermost position the reactivity of the facility is ~0.25 k_{eff}. The reactor is quenched rapidly by de-energization of electromagnets holding the control units, dropping the units down. The fission pulse is produced when the pulse unit (an aluminum cylinder) flies quickly through the reactor core central axial channel. The cylinder is 0.065 m in diameter and 0.4 m long, the flight velocity is 15 m/s, efficiency is 1 k_{eff}. The total mass of fuel material in GIR2 reactor core is 178 kg.

The reactor core is set up on the reactor rack (Figure 2). The control devices and detectors monitoring and measuring reactor power level are also mounted on the rack. The reactor rack moves along the rails inside the facility's shielding structure. When in the inoperative state following pulse production, the GIR2 reactor core is enclosed in the dome of lead and steel reducing the residual radiation output from the reactor core down to the reactor room background.

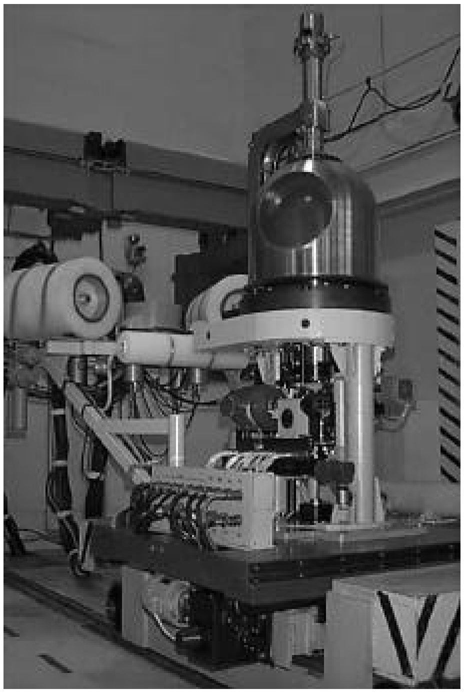

Figure 2 GIR2 Reactor

The reactor control system provides a fixed safe sequence of operations to move the reactor rack and control units remotely. Any hazardous actions that might be done by personnel at the specific stage of reactor operation are stopped automatically. The maximum static power is limited to 50 W. It is sufficient for reliable estimation of GIR2 reactivity before pulse production.

The measuring system involves doubled channels for measuring static power, power rate, fission pulse shape and reactor core temperature. The start state reactivity before pulse unit firing and the fission pulse parameters are estimated on the basis of measurements.

The tabular values of reactivity as a function of power rise period and the reactimeter data are used to estimate the reactivity. The reactimeter makes it possible to solve the reverse kinetics equations in real time using the data for reactor neutron flux evolution.

The sequence of operations in fission pulse production involves:

- bringing the reactor to the start above-critical state with regard to delayed fission neutrons ($0 \div 0.24$ k_{eff}.);
- producing the power level no less than 4 W in the same conditions to obtain rather high neutron density in the reactor core;
- firing the pulse unit and bringing the reactor to above-critical state in prompt neutrons.

These operations rapidly raise the reactor power up to $\sim 10^{10}$ W. The fission reaction is quenched by decreasing the density of reactor core material due to nuclear energy release. The flight of the pulse unit through the reactor core and the dropping of control units provided by a control system signal, prevents reactor power increasing after fission pulse production due to the delayed fission neutrons.

Without disturbances, a 0.24 $k_{eff.}$ transition above the criticality state in prompt neutrons generates about 7 MJ ($2.3 \cdot 10^{17}$ fissions) fission pulse. In this case the pulse width at half maximum is $3 \cdot 10^{-4}$ s and the fuel temperature increase is ~ 400° C. The gamma radiation dose in a pulse at the reflector outer surface is 600

Gy and the fast neutron fluence at the reflector hole is 10^{14} neutrons/cm^2. The linear dependence between energy release in pulse and subcriticality value, effective fission reaction thermal quenching; reduced level of reactivity disturbance due to the shielding reflector in use and the lack of inner cavities for carrying out irradiation test inside reactor core, considerably improve reactor safety and make it convenient for the teaching process.

TRAINING COURSE

GIR2 personnel provides the training course for University students. The students perform measurements, process them and write individual reports on the results obtained.

The training course is devoted to the following subjects:

- Measurement of neutron multiplication factor and production of reactor criticality. The isotopic neutron source is placed nearby the reactor core. The multiplication factor is estimated and the value of reverse multiplication is plotted versus the height of control units lifting. The varying shape of the curve is demonstrated for different positions of neutron detectors and neutron source adjacent to the reactor core.
- Estimation of reactor reactivity versus excursion period. Based on the measured excursion period, GIR2 reactivity is estimated for several above-critical states. The data obtained are compared with those calculated by reactimeter. The value of reactivity does not exceed 0.5 $k_{eff.}$
- Study of reactivity variations versus reflector characteristics. The increase of reactor reactivity is demonstrated when the pieces of steel or polyethylene are placed in the reflector hole and the control units are in fixed position.
- Estimation of reactor subcriticality by dropping the control units. The value of reactor subcriticality is estimated using the known relationships between initial reactor power and integral number provided by measuring channels after dropping the control unit.
- Measurement of reactivity temperature coefficient. The decrease of reactor reactivity is demonstrated for the fixed position of control units when the reactor core is heated due to the static or pulse energy release.
- Prediction and experimental estimation of reactor pulse parameters. The theoretical value of energy release in pulse is estimated based on the reactivity value measured in pulse production and the value of the reactivity thermal coefficient. This energy release value is compared with that obtained in the experiment on fission pulse production.
- The devices involved in GIR2 control and measuring systems are used in the training course.

CONCLUSIONS

The successful performance of training courses confirms the feasibility of using technological pulse nuclear reactors, in particular at GIR2 facility, as a relevant teaching aid. The combined training course comprising nuclear reactor physics, nuclear safety and dosimetry are planned to be performed in the future. Thus the students will become familiar with nuclear facilities operating at VNIIEF and obtain practical operational experience and experimentation at such facilities, as well as better theoretical knowledge. The elaboration of the training course is also useful to maintain and improve the skill of VNIIEF personnel by using themselves as instructors. The authors consider that such costly facilities as GIR2, if they have been already constructed, should be used, among other things, in training programs. The most acceptable way is to cooperate with the other educational institutions and create one-month summer schools (including the international ones) for training students at VNIIEF facilities, as well as for their joint recreation.

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KEY WORDS

Pulse nuclear reactor, design features, power excursions, education, training, University students.