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RFNC-VNIITF Physical Experimental Division and a Short Historical Sketch of Critical Mass Measurements

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This report describes the administrative structure, topics and the research base at RFNC-VNIITF Physical Experimental Division. It also includes a brief overview of the initial stages of investigations of nuclear criticality safety on experimental assemblies and benches in the Division. The report mentions the names of the principal developers and investigators concerned with nuclear criticality safety.

RFNC-VNIITF Physical Experimental Division was founded on April 5, 1955 at the same time the Instiute was founded. The team of scientific workers who formed the initial staff of the Institute came from three sources: VNIIEF (Arzamas-16), OIYAI (Dubna) and Radio-biological Laboratory which in 1955 was located on the site of the present VNIITF. The Physical Experimental Division has grown considerably since its inception (from 100 persons in 1955 up to 840 persons in 1995) and so did its experimental base structure. The Division structure is presented on the schematic in Fig.1.

Aside from investigations related to defence themes, the Division performs conversional work: it is engaged in:

- the development gamma-irradiating installations for medical and industrial purposes;
- development of a research laser and electro-physical systems;
- experimental technologies for work in laser thermonuclear fusion;
- microlithography;
- microbiology;
- investigations of power nuclear reactor safety;
- ecological research;
- improvement of fissile material protection, control and accounting systems;
- investigations of tritium effects on the materials of the perspective thermonuclear reactors;
- research into the field of peaceful use of nuclear and explosive technologies.

In the past 5-7 years work on defence themes has been significantly reduced. Beginning in 1994 the Division together with the Institute were involved in work on projects under contracts with the International Science and Technology Center: at present the specialists of the Division take part in two projects where the Division serves as a lead organization in five projects under subcontracts.

To perform its work, the Division has to use the following physical installations and technological sections:

- pulse nuclear reactors with metal and solution-type cores (see Table 1);
- pulse generator of gamma-bremsstrahlung - IGUR-3 (Table 2) - pulse generator of gamma-bremsstrahlung and electromagnetic pulse - EMIR (Table 3);
- laser installations based on neodymium doped glass (SOKOL-2, FILIN, etc);

- laser with nuclear pumping on the basis of the reactor EBR-L;
- a set of technological sections for handling of fissile and radioactive materials in any aggregation state (solid, fluid or gaseous one);
- pulse and static generator of 14 MeV neutrons in the Ural Regional Center for Neutron Therapy of Oncologic Diseases; the Center is situated at the Division;
- isotopic gamma-irradiators with radioactivity up to 70 kCi;
- technological sections for different coatings, for manufacturing thin films, X-ray mirrors, laser targets, etc;
- mobile instrumentation units to register the parameters of fast-running processes under test site conditions;
- assemblies of fissile materials and stands for investigations of nuclear criticality safety. The stands include ROMB facility consisting of a criticality vertical-lift machine and a 14-MfV neutron generator.

At the initial, organizational period of the Division (1955-1960) one of its main tasks was the experimental determination of neutron constants of fissile and inert materials in different structural combinations. Such investigations were performed by means of models under conditions approaching the critical state.

A group of researchers headed by Prof. Igor Pogrebov, who still works in the Division, continued measurements (which were begun in Dunba) of 14-Mev neutron transport in using a plane-shaped model. The model consisted of layers of depleted metallic uranium and lithium deuteride; in the center of the assembly the target of neutron generator of 14 MeV neutrons has been placed.

Aside from I. Pogrebov, the group included Yury Tuturov, Anatoly Saukov, Ivan Anisimov, Ruf Komarov and other specialists.

For criticality research using models with a spherical form it became necessary to design and to construct a special building and a facility for conducting criticality measurements.

The design and construction of the facility was done at rapid pace. By the beginning of 1958 all the mechanical units and stand control systems were ready. This equipment consisted of a remote-controlled mechanical stand for gradually drawing together two critical assembly parts. The top part was immobile and the bottom was moved from below towards the top part by means of a leading screw; the rise rate has been chosen taking into account safety conditions. The major safety feature, as the machine approached critical state, was a unit which consisted of a piece of hardware of plate-like form suspended by means of an electromagnet. Whenever an the emergency signal was generated, the power supply to the magnet would be turned off, the plate would separate from the magnet and all of the movable part of the critical assembly would drop downwards. This transformed the system to the subcritical state.

According to the intentions of the system's developers the core was to be universal and consisting of a set of twenty hemispherical shells out of U-235 enriched up to 90 per cent. The completely assembled system of these shells has a small supercriticality (T - 20s).

The stand was put into operation in March 1958 by a group of specialists headed by Victor Gavrilov, the first Head of the Physical and Experimental Division. Lev Poretzky, Yuly Milovanov, Michael Popov, Vladimir Gnevshev, Nickolay Raspopin and Pavel Samarin.

The first experimental projects included:

- measurement of neutron and gamma background of the uranium shells (the responsible person was L.Poretzky);
- criticality measurements with uranium and plutonium shells (the responsible person - Ju.Milovanov);

- measurement of neutron life time in different uranium assemblies, reflected and bare. The responsible person was Ziyat Al'bikov who now works at NIIZT (Moscow).

In 1962 the core was reconstructed: some central components of the core were removed. As a result, a cavity was formed inside the core. The decrease in mass of fissile material was compensated for by installing a thick outer copper shell. The central core cavity was used for placement of various irradiated samples there. Later, the stand had undergone several more stages of modernization.

Unfortunately, on April 5, 1968 a serious accident took place while work was being conducted on the stand. That day an experiment was being prepared to determine the contribution to the EBR reactor reactivity of a component which contained hydrogen. The component was being placed in the center of the center of the assembly.

For this purpose a polyethylene ball was placed into the cavity of the assembly of U-235 located on the stand. The resulting system was placed on the stand in such a way that its equatorial plane coincided with the boundary of the adjointing two external massive hemispheres of U-238. The U-235 parts were assembled in the raised upper hemisphere of U-238 and the partially lowered (by 30 mm instead of 130 mm) lower hemisphere of U-238.

Then one of the experimenters began to lower the upper hemisphere by means of a crane and the other guided it by hand into the required position.

Right before the lowered hemisphere coincided with the equatorial plane, the system turned critical: there was a neutron burst.

The first researcher received a dose equal to 800 rem and lived two months after the accident. The second was subjected to irradiation with dose equal to ÿ3000 rem and died on the third day.

Causes of the accident:

1. The lower hemisphere out of U-238 had not been lowered to a safe distance after the previous experiment was performed.
2. The power unit of the detector designed to signal in case of an increase in the neutron flux had been turned off.
3. The fission counter monitor had been switched to the most rough range.

Both of the experimenters had a lot of experience in working with critical assemblies. In this case, they assumed that the distance from the boundary of assembly to the lower hemisphere would provide the necessary margin of subcriticality. The alarm systems had not been turned on for the same reason. Over-confidence of the experimenters cost them their lives.

The attendant circumstances were:

- absence of the third, inspecting, experimenter-radiation supervisor on the team;
- haste in the preparation of the experiment: the work was performed on the last working day of the week.

More detailed technical data on this accident will be published by us in the nearest future.

Investigations of nuclear safety and measurements of nuclear constants have been performed and are being performed using this stand at our Institute. At the present V. A. Teryokhin, V. D. Perezhogin, Yu. A. Sokolov are the main investigators. The results of this work will be presented in detail in another report.

Table 3.

Regime	Accumulated energy of generator pulses, GNP	Duration of brems-strahlungpulse	Accele-rating Tube Voltage	Accele-rating Tube Current	Dose Rate at Anode	Dose Rate at R=1 ì	Dose at Anode
	kJ	ns	U	I	Rad /s	Rad/s	Rad
1	290	70	5.0	65	$8x10^{11}$	$2x10^9$	
2	580	75	5.0	100	$2x10^{12}$ 10^{12}	$2.5x10^9$ $4x10^9$	
Regime of the extracted electron beam							
3	220	120	3.3	65-full, 20-used	$<200\ J/cm^2$		

Electromagnetic pulse parameters:

Electric field strength is 30 - 300 kV/m.
Magnetic field strength is 80 - 800 À/m, at pulse duration 2.5 mcs, with 25 ns front of pulse rising.

Table 1

Specifications of reactor	IGRIK	EBR-L	BARS-5	YAGUAR
Average neutron energy, MeV	0.7	0.65	1.3	1.1
Number of fissions per pulse	$1.8x10^{18}$	$1.5x10^{17}$	$2.2x10^{17}$	$8x10^{17}$
Duration of fission pulse, mcs	2300	60	40	800
Dimensions of the internal channel for irradiation in Core, cm	31x50	12.5x30	6x18	12x32
Neutron Fluence in Channel, n/cm^2	$1.5x10^{15}$	$3x10^{14}$	10^{15}	$1.2x10^{15}$
Gamma-radiation Dose in Channel, Rad	$1.4x10^{6}$	-	$2x10^{5}$	-
Neutron Fluence in Core Channel, n/cm^{2}xs	$0.7x10^{18}$	$5x10^{18}$	$2.5x10^{19}$	$1.5x10^{18}$
Fluence of neutrons in Core, n/cm2	$3x10^{15}$	$5x10^{14}$	$2x10^{14}$	
Dose of gamma- radiation in Core, Rad	10^{5}	-	$2x10^{4}$	-

Table 2

Regime	Accumulated energy of generator pulses, GNP	Duration of brems-strahlungp ulse	Accele-rating Tube Voltage	Accele-rating Tube Current	Dose Rate at Anode	Dose Rate at R=1 ì	Dose at Anode
	kJ	ns	U	I	Rad /s	Rad/s	Rad
1	300	25	5.8	55	$4x10^{11}$ S=30cm^2	10^{10}max	10^{4}
2	300	25	6	60	$7x10^{12}$ oper.reg.	$2x10^{9}$	10^{5}
3	300	80	5.8	80	$2.5x10^{12}$	$3x10^{9}$	$2x10^{5}$
4	300	80	5.8	70	$4x10^{11}$ S=300cm2	$7x10^{9}$	$3x10^{4}$
5	300	< 4 mcs	1	30	10^{10}	10^{7}	

Regime for generating two serial pulses

6	150+150	1.50-220+ +15-60	2.2+2.2	25+25	$3x10^{10}$+ +3x1010	up to 10^{8}+10^{8}	

Electron beams

7	300	30-400 ns	< 6.0	< 30	-	-	-

Maximum energy density of the beam cross-section is 300J/cm^2

Total beam energy is 10^4 kJ

Average electron energy is 2.5 MeV

Figure 1.

RFNC - VNIITF

Composition of Physical & Experimental Division

DIVISION HEAD

Scientific & Research Departments

Department of investigations into the action of nuclear explosion factors and hydrodynamic instability

Department of testing ground physical measurements and irradiating gamma - installations

Department of X-ray measurements and laser installations

Department of materials technology, radiation and nuclear technologies

Department of electrophysical installations

Design Department

Calculation - theoretical laboratory

Department of nuclear reactors, critmass and constants investigations

Deputy Head Division

Services department providing the perfomance of experimental investigations

Personnel:

Scientific and engeneering & tehnical workers 445

Workers, employces 395

Total: 840 people