A brief description of the VNIIM's facilities
for measuring of neutron flux and neutron fluence rate.

The laboratory of radionuclide and neutron measurements at VNIIM (St-Petersburg, Russia) possesses facilities for accurate measuring neutron flux and neutron fluence rate, nuclear-physical constants and carrying out investigations in nuclear physics.

The national standard of neutron fluence and neutron fluence rate comprises five measuring facilities. Neutron field shapers are used as an auxiliary equipment: spherical moderators of various diameters, a facility with a collimator device and different neutron detectors: a long counter, a scintillation spectrometer with a n-y separation circuit, ^He counters in the spherical moderators. When measuring neutron fluence rate by the activation method, a scintillation gamma-radiometer, (3-x and 4тс-|3-y coincidence counters are employed.

At the laboratory the following types of radionuclide neutron sources are used:

- photoneutron sources: ***Ra-Be(γ, n)*** and ***Sb-Be(γ, n)***
- alpha-beryllium sources: ^{238}***Pu***, ^{239}***Pu***, ^{226}***Ra***, ^{244}***Cm***, ^{241}***Am*** and ^{210}***Po***
- spontaneous fission sources ^{252}***Cf*** and ^{244}***Cm***.

The staff of the laboratory is engaged in improvement of the experimental equipment, development of measuring procedures, measurement of neutron physical constants and calibration of neutron sources and radiometers.

1. The standard incorporates the following facilities for neutron flux measurement:

1.1. The "УЭН-1" facility (associated particle method).

The facility consists of a 4 m diam. spherical graphite moderator with a 0,4 m diam. cavity at the center (see fig. 1). In the moderator there are vertical and horizontal channels. Thermal neutron detectors are located in the radial channels, in the movement of which lengthwise the channels, the form of the distribution function for thermal neutrons, being produced in graphite by moderation of fast neutrons, is measured. The vertical channel is used to locate a radionuclide source at the centre of this cavity. To calibrate the moderator a neutron generator target is centrally placed into the cavity through the horizontal channel, and neutron flux from the ***$T(d,n)^4He$*** reaction is determined by the associated particle method.

The "УЭН-1" facility is designed for measuring the neutron flux of radionuclide neutron sources at energies from 0,024 to 15 MeV within the range of 1-10^3 n/s -1-10^8 n/s with an error from 1,1% to 1,8%.

The experimental studies verified the theoretical model of the constant sensitivity zone, existing in an extended graphite moderator; in this zone the thermal neutron fluence rate is proportional to the fast neutron flux of the source with an error of 2% independently of their energy distribution.

This effect is used for calibrating neutron sources against the flux with an error of (3-4)% at the confidence level of 0,95. In addition it has been found by the experiment that in the range of the moderator constant sensitivity, the cadmium ratio is proportional to the logarithm of the neutron source average energy.

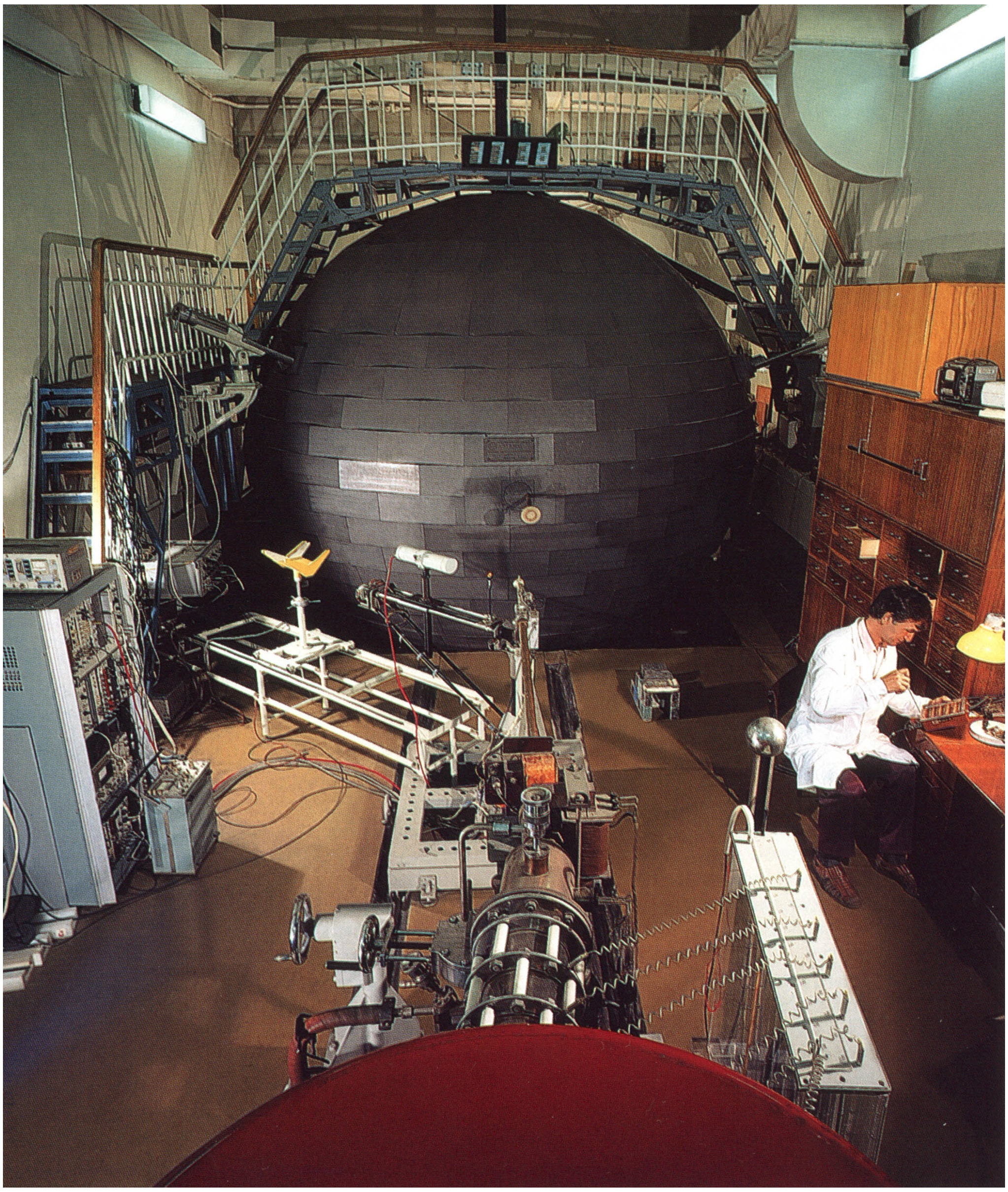

Fig. 1. The "УЭН-1" facility

1.2. The "УЭН-2" facility (manganese bath method).

The facility comprises a 0,8 m diam. bath with a ***$MnSO_4$*** solution, a scintillation gamma-radiometer, immersed into this solution and connected with electronic measuring instruments as well as a device for stirring the solution (fig. 2). The "УЭН-2" facility is designed for measuring the neutron flux of sources within the range $5\text{-}10^5$ n/s - $5\text{-}10^7$ n/s at the energies from 0,024 to 4,6 MeV with an error from 0,7% to 1,2%.

Fig. 2. The "УЭН-2" facility

1.3. The "УЭН-3" facility (gold foil activation method in distilled water).

The facility consists of a 1,3 m high, 1,1 m diam. bath filled with distilled water, a remote operated system for moving the activation detector and the source support (fig. 3). The activation detectors: gold and indium foils, various in thickness with diam. 10 and 20 mm, cadmium screens are parts of the facility.

The β-γ and $4\pi\beta$-γ coincidences facilities are applied for induced activity measurements. A constructional feature of this facility is the system for moving the detector and the source support, providing a minimum neutron field distortion and moving the detector relative to the source center with an error not over 0,1 mm.

The facility is used to measure neutron flux of radionuclide sources of the type: ***Ra-Be(α, n)***, ***Pu-Be(α, n)***, ^{252}***Cf***, ^{244}***Cm*** over the range of 1-10^6 n/s - 5-10^7 n/s with an error 1%.

Fig. 3. The "УЭН-3" facility

2. The "УЭПТН" facility providing a standard field with stationary fluence rate of thermal neutrons.

The "УЭПТН" facility comprises a polyethylene block in the form of a cube, 330 mm on edge, provided with a central cavity 120 mm and 6 channels passing through the edge centre. This block is surrounded by a reflector consisting of organic glass plates 180 mm thick. Six plutonium beryllium sources are located in the channel at a distance of 20 mm from the central cavity boundary (fig 4).

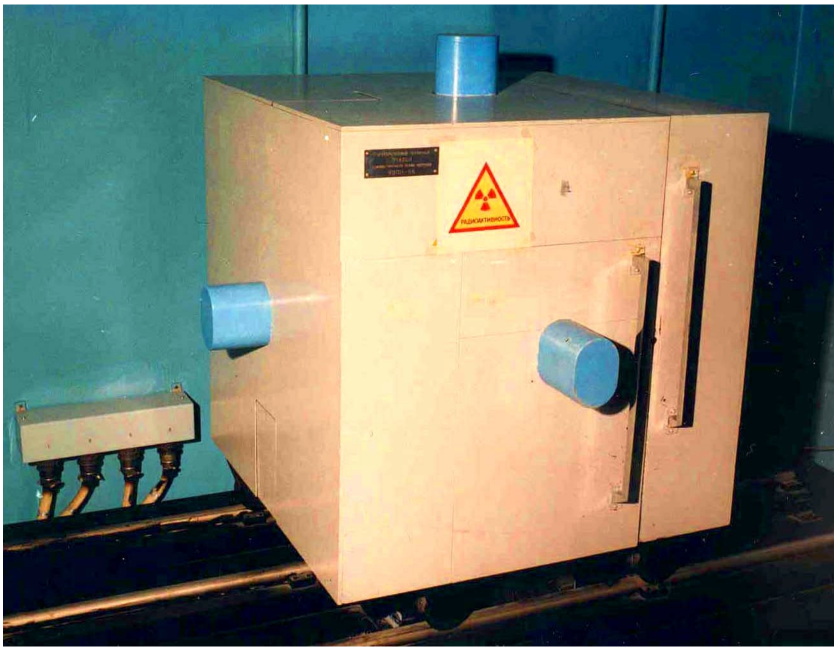

Fig.4 . The "УЭПТН" facility

The thermal neutron fluence rate in the moderator cavity, measured by the gold foil activation method, accounts for $6{,}12 \cdot 10^{8}$ n/cm^{2}. The isotropic and uniform field of thermal neutrons in the central zone has the effective temperature 314±5 K and is characterized by an epithermal parameter value of α = -(0,17±0,008). This facility is employed as the standard of the thermal neutrons field with stationary fluence rate on irradiation of the activation defectors made in thin foil form.

3. The scintillation spectrometer with a n-γ separation circuit.

At the laboratory the stilbene-crystal scintillation spectrometer of neutron has been developed for separating the neutron and gamma ray impulses (fig. 5). The detector unit is made in the form of a cylinder, 80 mm in diameter and 200 mm in height. The stilbene crystal is 40 mm in diam. and 20 mm in height. The electronic system is stabilized against a signal from a light-emitting diode. The energy measurement range is:

for neutron radiation - (1-16) MeV;

for gamma radiation - (0,3-8) MeV.

This spectrometer is applied to study the energy distribution in mixed gamma-neutron radiation fields, to monitor radiation flux from the ***T(d,n)^{4}He*** and ***D(d,n)^{3}He*** reactions, as well as to determine the neutron fluence rate in these reactions using both the neutron cross-section on hydrogen and the ***n-α*** coincidence method.

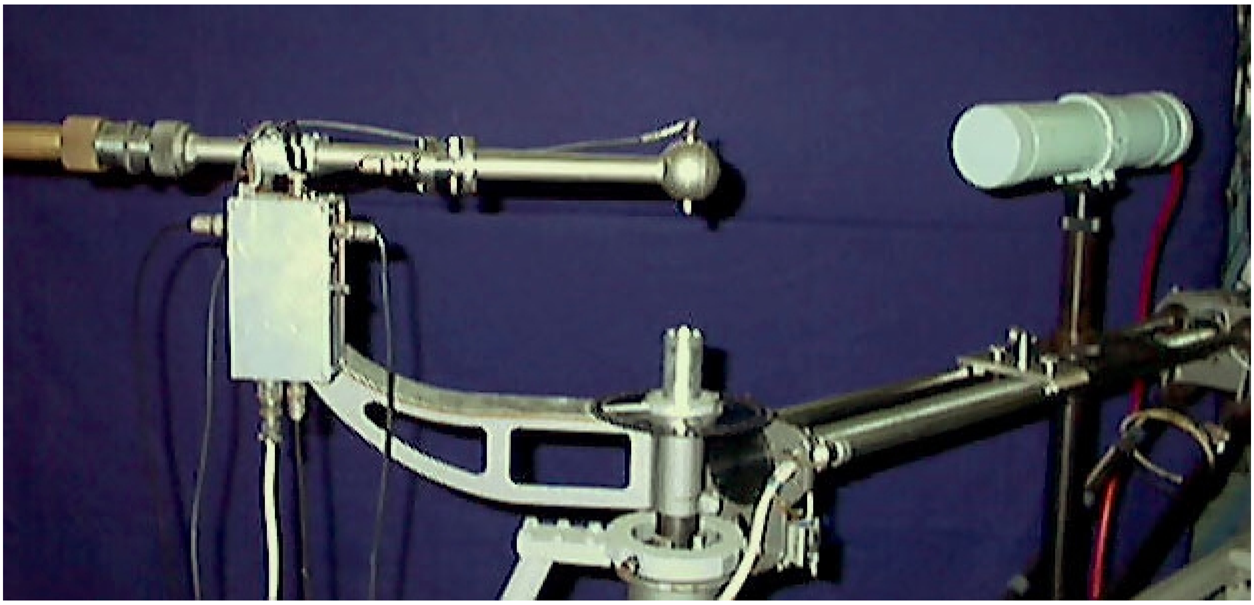

Fig.5 . The scintillation spectrometer

4. The neutron long counter.

The neutron long counter (fig 6) has been developed at the laboratory. This counter differs from the standard model by the following:

- the central perforated part is made of polyethylene;
- shielding of the back and lateral surfaces is made of boron polyethylene covered with a cadmium shell 1 mm in thickness;
- stabilized electronic circuit;
- proportional counter of thermal neutrons filled with $^{3}\boldsymbol{He}$ at pressure 7 atm 32 mm in diameter and 300 mm m length, type CHM-18.

Dimensions of the long counter:

Diameter - 40 cm;
Height - 50 cm;
Working surface - 324 cm^2

Instability of the counting rate for 8 hours is equal to 0,1%.

The neutron detection efficiency from a $^{252}\boldsymbol{Cf}$ spontaneous fission source is equal to 4,7%.

On the calibration ruler located between the source and the front surface of the long counter there is a system of remote distance counting in the range of 0 - 2,5 m with an error of 0,5 mm. The long counter of neutrons is used to investigate the neutron fields produced by radionuclide neutron sources, to define radiation source asymmetry and the wall scattering radiation contribution as well as to calibrate sources.

5. **The facility with a collimator device.**

At the laboratory the facility with a collimator device (fig. 6) has been developed, consisting of a moderator-field shaper and a calibration ruler. The moderator-field shaper is a boron polyethylene cylinder, 500 mm in diameter and 500 mm in height. Along the axis of the cylinder there is a through channel. One end of this channel is plugged with a stopper, 250 mm in length; the collimator with a conical bell mouth 50x200 mm is inserted into the other end. At the centre of the moderator the collimator and the stopper form a 50 mm diam. cavity where on the support a radionuclide source of fast neutrons is placed. The whole of the moderator except the front end surface is coated with a cadmium layer 1 mm thick.

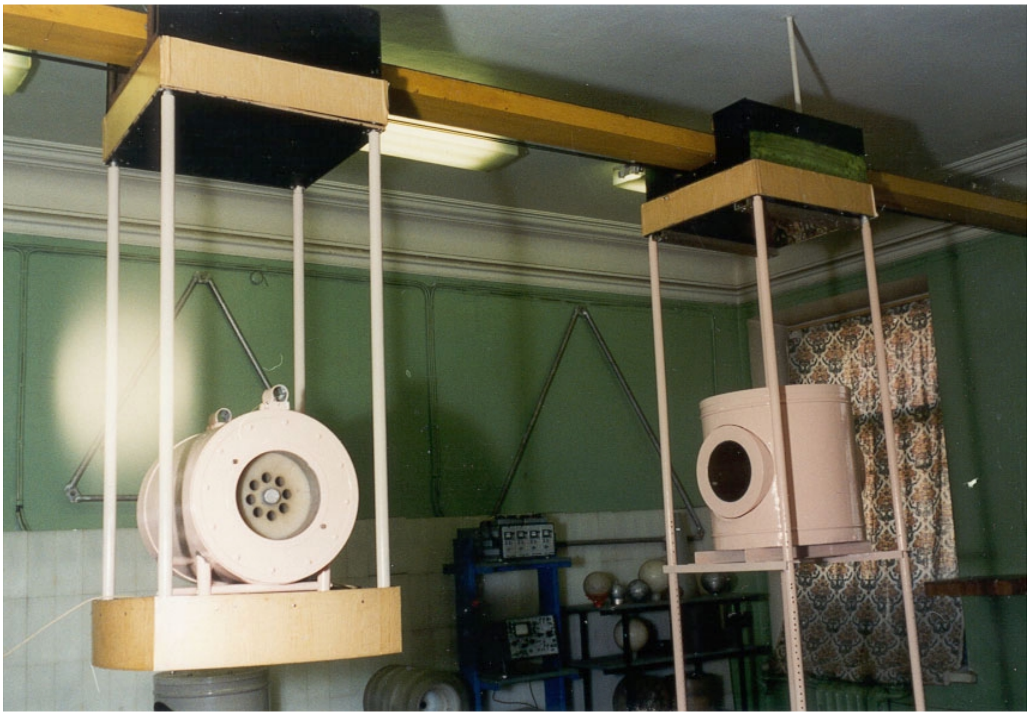

Fig. 6. The long-counter and the facility with a collimator

In calibration the moderator and the device are mounted on the calibration ruler. The collimator shielding attenuates the neutron flux beyond the working area of the neutron field a hundred times. The facility with the collimator device is used for calibration of fast and thermal neutron radiometers and dosimeters

- in the range of fact neutron fluence rate - $1{,}5 \cdot 10^1$ - $7{,}0 \cdot 10^3$ n/s-cm^2
- in the range of thermal neutron fluence rate - $1{,}0 \cdot 10^1$ - $2{,}5 \cdot 10^3$ n/s-cm^2
- in the range of equivalent neutron dose rates -10^1 – 10^3 mSv/h.

6. **The facility for rotating the activation detectors (foils).**

To measure the fluence rate of thermal neutrons with nonisotropic angular distribution the laboratory has developed the facility providing simultaneous rotation of the activation detectors in two mutually perpendicular planes with various speeds. As a result, the detector activity, induced in the field of an unknown angular distribution, becomes equivalent to the activity, induced in the isotropic field.

Structurally, the facility is a movable platform, where electric motors and a connecting gear are mounted. The detectors are fixed in a holder, arranged on a movable vertical bar, this enables the detector position to be changed along the vertical axis.

There exists a constructional version of the facility with a demountable rotation system that makes possible to mount this assembly and the detector directly onto the calibration ruler.

7. The low-background facility for induced activity measurements.

The low-background facility for measuring induced activity in irradiation of foils in a neutron field has been developed at the laboratory. The facility is characterized by two constructional features:

- Massive shielding made from pure electrolytic copper;
- 2 scintillation measuring channels, stabilized against the peak of a light-emitting diode.

As a result of researches, the minimum detected activity of ^{198}Au accounts for 0,1 Bq.

8. The neutron generator.

The neutron generator is utilized for producing reference monoenergetic neutron fields at the energy of 2,5 and 14 MeV; for calibrating neutron radiometers and spectrometers as well as for determining experimentally the cross-section interactions of neutrons at 14 MeV by the activation method.

Basic characteristics of the generator:

- accelerating voltage 120-180 kV;
- ion current -1-10 μA; neutron flux at 14 MeV up to $5\text{-}10^{8}$ n/s;
- neutron flux at 2,5 MeV up to $5\text{-}10^{6}$ n/s;
- target diameter -14 mm (working area, enriched with tritium or deuterium -10 mm);
- location of the associated particle detector at an angle of 170° with respect to the ion beam (at a distance of 180 mm).

In accordance with its metrological purposes the generator has a number of constructional features:

8.1. The possibility for movement (along the rails) and the availability of a long vacuum ionowire (2,5 m) for simultaneous work with the graphite moderator (a target chamber may be located at the central cavity of a 4 m diam. sphere).

8.2. The target chamber construction ensures a minimum distortion of the neutron field, due to the reaction and gives the possibility to measure the associated particles in a fixed solid angle. The chamber is made in the form of a stainless steel sphere, 50 mm in diam. and has walls 0,8 mm thick. In the construction, provision is made for a special tube wherein the target, semiconductor, associated particle detector and limiting calibration diaphragms are mounted, the geometric factor reproducibility being achieved by replacing the target or detector.

8.3. The system for beam magnetic analysis provides separation of the atomic component of deuterium ions, required to maintain monoenergetic neutron radiation.

8.4. The neutron generator operates without the target cooling whilst this limits the ion current value (10 μA) and consequently the neutron flux value, nevertheless if affords an essential decrease in distortion and attenuation of the initial neutron radiation, that is of importance in calibrating measuring devices and carrying out the cross-section measurements.

8.5. The remote operated system for movement of activation and small in size neutron detectors allows them to be located in the angle range of ±120° relative to the ion beam at intervals of 0,5°, and in the distance range of 5-700 mm at an interval of 0,1 mm.

A measuring ruler is applied for calibrating large-sized radiometers over the distance of 0,3-3 m.

8.6. The possibility of obtaining time synchronization when the solid angle of associated particle registration coincides with a corresponding neutron emission angle in accordance with ***T-D*** and ***D-D*** reaction kinematics, is practically used to determine fluence rate by a ***n-α*** coincidence method, to calibrate neutron dosimeter.