TOMSK POLYTECHNIC UNIVERSITY

ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Министерство науки и высшего образования Российской Федерации
федеральное государственное автономное
образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

Инженерная школа ядерных технологий
Направление подготовки 14.04.02 Ядерные физика и технологии
Научно-образовательный центр международного ядерного образования и карьерного сопровождения иностранных студентов ТПУ

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Тема работы
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Студент

Группа	ФИО	Подпись	Дата
0АМ1Ф	Серебрякова Е.И.		

Руководитель ВКР

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент НОЦ ЦМЯО ИЯТШ	Силаев М.Е.	к.т.н.		

КОНСУЛЬТАНТЫ ПО РАЗДЕЛАМ:

По разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОСГН ШБИП	Меньшикова Е.В.	к.ф.н.		

По разделу «Социальная ответственность»

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОЯТЦ ИЯТШ	Передерин Ю.В.	к.т.н.		

ДОПУСТИТЬ К ЗАЩИТЕ:

Руководитель ООП	ФИО	Ученая степень, звание	Подпись	Дата
Безопасность и нераспространение ядерных материалов	Верхотурова В.В.	к.и.н.		

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School of Nuclear Science & Engineering
Field of training: 14.04.02 Nuclear Science and Technology
Specialization: Nuclear Safety, Security and Non-Proliferation of Nuclear Materials
Research and Training Centre for International Nuclear Education and Career, School of Nuclear Engineering

MASTER THESIS

Topic of research work
Spectrometric control of neutron fields parameters in the vicinity of the IRT-T reactor

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Student

Group	Full name	Signature	Date
0AM1Ф	**Ekaterina I. Serebryakova**		

Scientific supervisor

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	**Maxim E. Silaev**	**PhD**		

ADVISERS:

Section “Financial Management, Resource Efficiency and Resource Saving”

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Ekaterina V. Menshikova	PhD		

Section “Social Responsibility”

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Yuriy V. Perederin	PhD		

ADMITTED TO DEFENSE:

Programme Director	Full name	Academic degree, academic rank	Signature	Date
Nuclear Safety, Security and Non-Proliferation of Nuclear Materials	Vera V. Verkhoturova	PhD		

Tomsk – 2023

LEARNING OUTCOMES

Competence code	Competence name
Universal competences	
UC(U)-1	Ability to make critical analysis of problem-based situations using the systems analysis approach, and generate decisions and action plans.
UC(U)-2	Ability to run a project at all life-cycle stages.
UC(U)-3	Ability to organize and lead the teamwork and generate a team strategy to achieve the target goal.
UC(U)-4	Ability to use modern communication technologies to realize academic and professional interaction.
UC(U)-5	Ability to analyze and account for cultural diversity in the process of intercultural interaction.
UC(U)-6	Ability to set and pursue individual and professional activity priorities and ways to modify professional activity based on the self-esteem.
General professional competences	
GPC(U)-1	Ability to formulate goals and objectives of the research study, select assessment criteria, identify priorities for solving problems.
GPC(U)-2	Ability to apply modern research methods, evaluate and present the resultsof the performed research.
GPC(U)-3	Ability to present research outcomes in the form of articles, reports, scientific reports and presentations using computer layout systems and office software packages.
Professional competences	
PC(U)-1	Ability to organize and control the performance of personnel work related to accounting and control, physical protection of nuclear materials and radioactive substances in storage, use and transportation at nuclear facilities.
PC(U)-2	Ability to develop measures to ensure the safe operation of technical means, equipment, devices and mechanisms, draw up and analyze scenarios of potential accidents, develop methods to eliminate the likelihood of failures and reduce the risk of accidents.
PC(U)-3	Ability to apply research methods and calculations of modern systems, instruments and devices in the field of nuclear physics, physical measurements, control and physical protection of nuclear and radioactive materials technologies.
PC(U)-4	Ability to create theoretical and mathematical models describing the propagation and interaction of radiation with matter, the effect of ionizing radiation on materials, humans and environmental objects, neutron multiplication in systems containing fissile materials.
PC(U)-5	Ability to carry out independent experimental or theoretical research to solve scientific and industrial problems using modern equipment, calculation and research methods.
PC(U)-6	Ability to analyze technical and computational-theoretical developments, take into account their compliance with the requirements of laws in the fieldof industry, ecology and safety and other regulations.

PC(U)-7	Ability to apply methods of optimization, analysis of options and accounting for uncertainties in the design of accounting, control and nuclear security systems for the nuclear fuel cycle.
PC(U)-8	Ability to draw up technical assignments, use information technology and application software packages in the design and calculation of facilities, equipment and systems used to monitor ionizing radiation levels in the management of radioactive materials and waste.
PC(U)-9	Ability to use information security technologies, to automate work processes associated with the use of nuclear technologies, to develop algorithms and software for security purposes
PC(U)-10	Ability to develop technical requirements and assignments, to use information technology, legal and regulatory norms and standards for organizing and conducting safe operations related to internal and external movements of nuclear and radioactive materials, installations, export and import of equipment and materials.
PC(U)-11	Ability to conduct training sessions and develop instructional materials for the training courses within the cycle of professional training programs (bachelor's degree).

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Level of education: Master degree program
Research and Training Centre for International Nuclear Education and Career, School of Nuclear Engineering
Period of completion: spring semester 2022/2023 academic year

Form of presenting the work:

Master Thesis

SCHEDULED ASSESSMENT CALENDAR
for the Master Thesis completion

Deadline for completion of Master's Graduation Thesis:	06.06.2023

Assessment date	Title of section (module) /type of work (research)	Maximum score for the section (module)
15.03.2023	*Goal and objectives setting*	5
17.03.2023	*Special literature selection and studying*	5
27.03.2023	*Literature development*	5
28.03.2023	*Conducting dosimetric measurements in the physical hall of the research reactor by method No. 1*	10
31.03.2023	*Conducting dosimetric measurements in the physical hall of the research reactor by method No. 2*	10
07.04.2023	*Construction of neutron radiation spectra*	20
21.04.2023	*Analysis of methods*	15
02.05.2023	*Writing a research program*	10
15.05.2023	*Preparing an explanatory note*	10
30.05.2023	*Summarizing*	10

COMPILED BY:

Scientific supervisor:

Position	Full name	Academic degree, academic status	Signature	Date
Associate professor	Maxim E. Silaev	PhD		

APPROVED BY:

Program Director	Full name	Academic degree, academic status	Signature	Date
Nuclear Safety, Securityand Non-Proliferation ofNuclear Materials	Vera V. Verkhoturova	PhD		

Content

Abbreviations

IAEA – International Atomic Energy Agency;

ICRP – International Commission on Radiological Protection;

GSR – General Safety Requirements;

HEC – Horizontal Experimental Channel;

FA – Fuel assemblies;

CPS – Control and protection system rods;

EP – Emergency protection;

SR – Shim rods;

CR – Control rods

SWOT – Strong, weaknesses, opportunities, threats;

RSS – Radiation Safety Standards.

1 Neutron spectrometry

1.1 Requirements for measuring the neutron spectrum at a research reactor

A research nuclear reactor has a number of specific features (the size of the reactor core, the energy of neutron fluxes, etc.), unlike other sources of neutron radiation. An important difference is the presence of experimental channels that are conductors of ionizing radiation from the core to the irradiated sample. Although these experimental channels have special design solutions for protection from direct radiation (protective gates), they are nevertheless the most "weak" point in the biological protection of the reactor. In the case of ensuring radiation safety and protection from ionizing radiation and, above all, neutron radiation, such places at the research reactor cause special attention.

The number and location of experimental channels varies for different research reactors, but is usually quite large. The IRT-T reactor has 10 experimental channels located around the reactor in the horizontal plane of its section. There are a large number of vertical experimental channels, the number of which can change as needed [1].

Therefore, the first requirement for a neutron spectrometer used to study neutron fields near a research nuclear reactor is its mobility – the ability to carry out spectral measurements in various places of the physical hall.

The energy range of neutrons measured by the spectrometer must correspond to the spectrum of the reactor. Thus, it is desirable to have a device that allows measuring neutrons from the thermal neutron region to maximum energies - the fission spectrum (about 10 MeV).

The intensity of neutron fluxes in a research reactor usually varies in a wide range, ranging from the value characteristic of the maximum power inside its core (about 10^{14} $cm^{-2}s^{-1}$ for thermal neutrons for the IRT-T reactor) to almost zero values. The ideal would be a neutron spectrometer that functions efficiently in the entire specified range. However, simultaneous measurement of both small and large neutron fluxes is a task for which a full-fledged technical solution has not yet been found.

During the operation of the research reactor, there is a change in power, which entails a change in the neutron flux. Compared to a nuclear power plant, changes in the neutron flux at a research reactor occur very often. Therefore, the efficiency of measurements is an additional requirement. Direct measurements, control of the spectrum and neutron flux characterize ideal research conditions [1].

There are several methods of neutron spectrum measurement were developed and implemented:

– methods by which the energies of charged particles are measured, which are obtained in nuclear reactions produced by neutrons;

– methods in which the neutron velocity is measured;

– threshold methods, in which the minimum neutron energy is a consequence of the effects produced by neutrons, such as radioactivity, gamma radiation;

– methods in which the neutron energy is distributed according to data from detectors (or detector configurations) that have different energy dependences of their sensitivity to neutrons.

This chapter describes the existing methods of neutron spectrometry.

1.2 Activation method

This method has found wide application in measuring constant neutron fluxes. Indicator substances are bombarded with neutrons with a certain flux for some time. New radioactive isotopes appear, which later decay and emit radiation quanta and charged particles.

The activity is proportional to the number of new nuclei formed, and it is the neutron flux that affects the activity. By measuring the activity formed in the indicator substances using radiometers and gamma spectrometers, the density of the neutron flux under study is calculated.

The indicators correspond to the general requirement for an acceptable half-life of the formed radioactive nuclei. If the half-life is too short, the activity of the substance decreases greatly during the time between irradiation and measurement and during measurement, and if the half-life is too long, the time to reach the saturating activity of the substance and the time to measure the activity itself becomes quite long. The substance must be free of admixtures of other isotopes in order to avoid distortion of indicators due to impurities [2].

For the spectral analysis of neutron radiation by the activation method, special sets of isotope indicators are recommended, which, in addition to the spectral-sensitive indicators, necessarily include $1/v$ indicators, in which the reaction cross-section monotonically decreases with increasing neutron energy without resonant emissions.

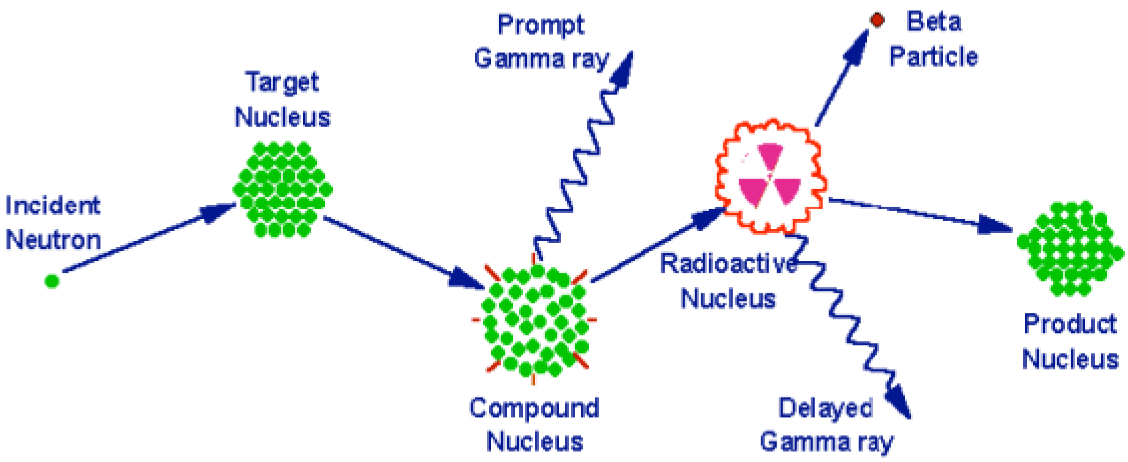

Figure 1.1 – The process of neutron capture by a target nucleus with the emission of gamma quanta

The activation method has advantages and disadvantages in comparison with other methods of neutron spectrometry. By choosing an indicator substance, it is possible to change the sensitivity of the activation method to different spectral energies in a wide range. The indicator substance can be made of small sizes. Due to its small size, the indicator substance does not affect the neutron flux. The indicators are not sensitive to gamma quanta and can be used for large gamma radiation fluxes. However, activation methods are very long and do not give results instantly. This method cannot be used with a rapidly changing neutron flux, for example, when the reactor power rises or decreases. Ultimately, activation methods are not suitable for measuring the neutron spectrum in real reactor operating conditions [3].

1.3 Methods using recoil protons

This method is based on the collision of neutrons with protons, followed by the registration of recoil protons. Since a neutron and a proton have approximately the same properties, a neutron transfers all its kinetic energy to a proton in a single collision. However, there is a possibility that the recoil proton can have any energy from zero to the maximum possible, as a result of which the relationship between the neutron energy spectrum and the recoil proton pulse height distribution is not simple.

Suppose that a neutron with kinetic energy E_n colliding with a proton at rest (Figure 1.2). To calculate the proton kinetic energy after the collision, one must apply the equations of conservation of energy and linear momentum using Q=0 and M_n=M_p. The result for E_p, the proton kinetic energy as a function of the recoil angle θ, is

$$E_p = E_n cos^2\theta \tag{1.1}$$

In a neutron-proton collision, the maximum value of angle θ is 90°, and the minimum 0°; therefore, the limits of the proton energy are $0 \leq E_p \leq E_n$. For neutron energies up to about 14 MeV, the (n – p) collision is isotropic in the center-of-mass system; as a consequence, there is an equal probability for the proton to have any energy between zero and E_n, in the laboratory system. That is, if $p(E)\ dE$ is the probability that the proton energy is between E and $E\ +\ dE$, after the collision, then

$$p(E)dE = \frac{dE}{E_n} \tag{1.2}$$

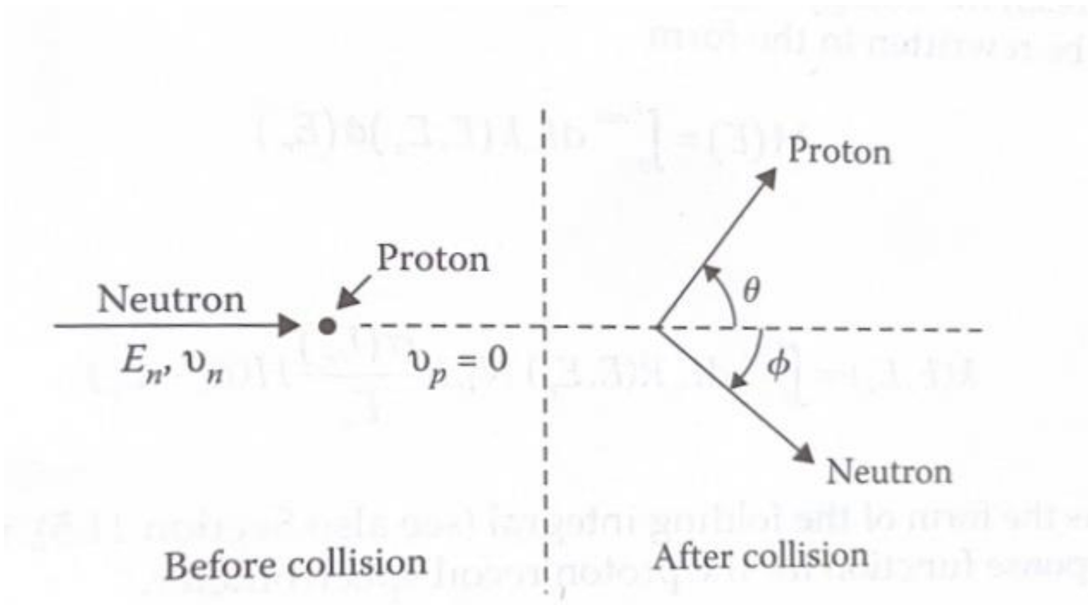

Figure 1.2 – Neutron-proton collision kinematics

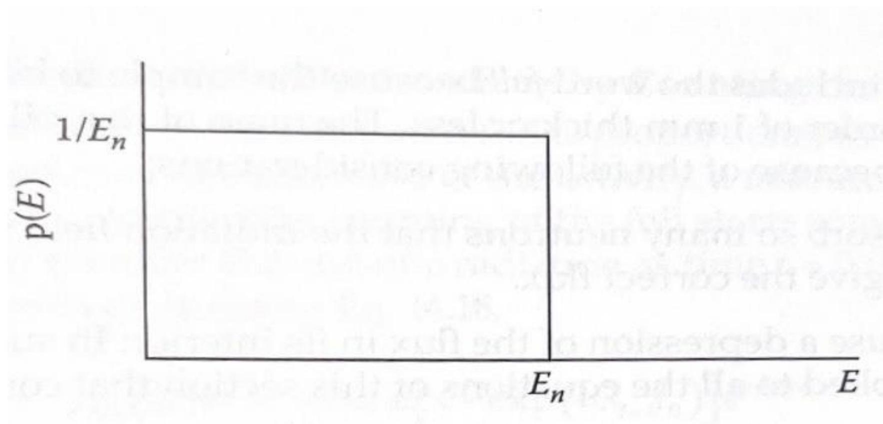

Figure 1.3 – Distribution of proton energy after collision (n, p), isotropic in the system of centers of mass of two particles

The function $p(E)$ is shown in Figure 1.3. What is important for the observer is not $p(E)$ but the proton pulse-height distribution produced by the detector. The relationship between the pulse-height distribution and the neutron spectrum is derived as follows.

Let

$\phi(E_n)dE_n$ = neutron energy spectrum = flux of neutrons with energy between En and $E_n + dE_n$

$N(E_p)\, dE_p$ = proton recoil energy spectrum = number of protons produced (by collisions with neutrons) with energy between E_p and $E_p + dE_p$

$R(E, E_p)\, dE$ = response function of the detector = probability that a proton of energy E_p will be recorded as having energy between E and $E + dE$

$M(E)\, dE$ = measured spectrum = number of protons measured with energy between E and $E + dE$

The measured spectrum $M(E)$ is the pulse-height distribution in energy scale. The response function $R(E, E_p)$ takes into account the finite energy resolution of the detector and the relationship between energy deposition and pulse height [4].

Assuming isotropic scattering in the center-of-mass system, the proton energy spectrum is

$$N\left(E_p\right)dE_p = N_H T \int_0^{E_{max}} \sigma(E_n)\phi(E_n)dE_n \frac{dE_p}{E_n} H(E_n - E_p) \tag{1.3}$$

Where N_H = number of hydrogen atoms exposed to the neutron beam

T = time of measurement of the recoil protons

$H(E_n - E_p)$ = step function; $H\left(E_n - E_p\right) = 1 | E_n \geq E_p$, zero otherwise

$\sigma(E_n)$ = elastic scattering cross section for (n, p) collisions

The measured energy spectrum is then given by

$$M(E)dE = \int_0^{E_{max}} dER\left(E, E_p\right)N\left(E_p\right)dE_p \tag{1.4}$$

In Eqs. 3 and 4, the energy E_{max} is the upper limit of the neutron energy spectrum. Equation 4 may be rewritten in the form

$$M(E) = \int_0^{E_{max}} dE_n k(E, E_n)\phi(E_n) \tag{1.5}$$

where

$$k(E, E_n) = \int_0^{E_{max}} dE_p R(E, E_p) N_H T \frac{\sigma(E_n)}{E_n} H(E_n - E_p) \tag{1.6}$$

Equation 1.5 has the form of the folding integral, while Eq. 1.6 gives the «composite» response function for the proton recoil spectrometer.

The main difficulty of spectrometric measurements using these detectors is the fact that if the measured flux contains neutrons of different energies, then the amplitude spectrum will be an overlay of these distributions from neutrons of different energies.

It is quite difficult to restore the original spectrum of the measured neutron flux from them, given that the instrument spectrum in addition to the neutron energy, a number of factors that are difficult to take into account also affect, such as the nonlinearity of the light output due to multiple scattering of neutrons in the scintillator and the edge effect due to the exit of the formed protons outside the scintillator, the dependence of the light output on the angle of motion of the recoil proton in the crystal relative to its main axis, the dependence of the light output on the temperature of the scintillator and many others [4].

If we talk about the hardware spectrum of a neutron flux with a continuous by the distribution of neutrons by energy in a sufficiently wide range, it is also necessary to take into account the dependence of the cross section *(n, p)* of the reaction on the energy neutrons, as well as the dependence of the efficiency of the detector of finite dimensions on the energy of neutrons.

Therefore, the restoration of the neutron spectrum from the hardware spectrum of recoil protons is a rather difficult task, as a result of which these devices could not be brought to commercial implementation.

Processing of experimental amplitude distributions of recoil protons in such spectrometers is carried out on a computer. But it is quite obvious that it is impossible to accurately take into account all these effects on the measured instrument spectrum by calculation. Therefore, in these programs it is necessary to use a priori information about the shape of the recovered spectrum and iterative procedures for approximating the calculated models to the measurement results [5].

1.4 Multi-ball method using neutron moderators

This method is based on the forced deformation of the spectrum of the measured flux using neutron moderators of various thicknesses with the measurement of the resulting integral density of the neutron flux. The measurement results obtained with a detector and with a detector sequentially placed in a cavity of moderators of various diameters are processed on a computer for the purpose of computational restoration of the spectrum the initial flow. For the first time, a spectrometer implementing this method was proposed back in 1960 and was called the Bonner spectrometer. In Europe and America, Bonner spectrometers have become very widespread. Many variants of its design have been developed, differing from each other both in the number of neutron moderator balls used (from 4 to 12) and the detectors used, and in the methods for obtaining spectral sensitivity functions and algorithms for computational reconstruction of the spectrum of the measured flux by the results of measurements using a complete set of neutron moderator balls (Figure 1.4).

The principle of operation of Banner spectrometers is that neutrons of the measured flux passing through a moderator (spheres) with different wall thicknesses are slowed down, scattered and partially absorbed by the moderator substance. All these processes lead to the transformation of the energy spectrum of the flow entering the detector. Thus, for each *i*-th sphere, the spectral sensitivity functions $R_i(E)$ differ from each other.

Figure 1.4 – Neutron moderator balls

In the small sphere, the deceleration is not as strong as the capture of thermal neutrons in the moderator. Low-energy neutrons are more likely to hit the thermal sensor and be detected while fast neutrons increase. Larger spheres have a greater degree of deceleration. Neutrons with low energy are absorbed by polyethylene and neutron capture occurs. The sensor detects high-energy neutrons. Figure 1.5 illustrates the response functions constructed for a range of different sizes of spheres, showing how the peak of the response function shifts to higher energies as the size of the sphere increases.

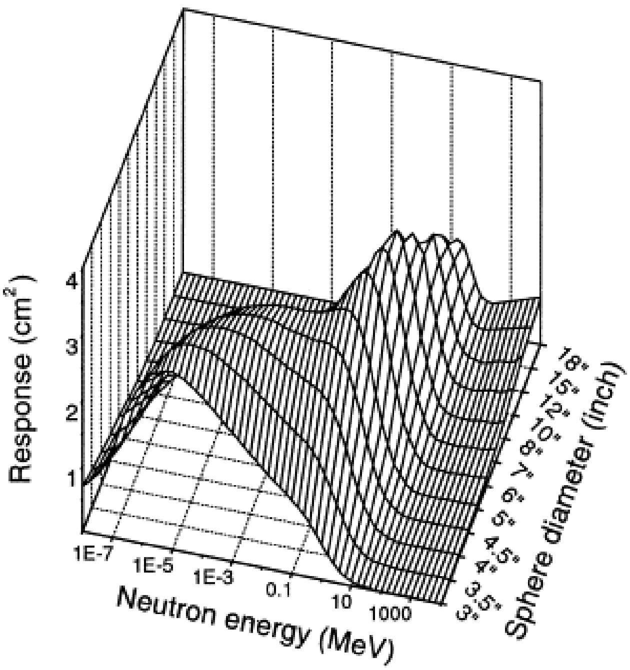

Figure 1.5 – Response functions for a Bonner sphere set

If sphere *i* has response function $R_i(E)$, and is exposed in a neutron field with spectral fluence $\varphi(E)$, then the sphere reading M_i is obtained mathematically by folding $R_i(E)$ with $\varphi(E)$, i.e.:

$$M_i = \int R_i(E)\varphi(E)dE \tag{1.7}$$

The integral, formally a Fredholm integral, extends over the range of neutron energies present in the field. Good approximations to $R_i(E)$ can be obtained from simulation calculations supported by measurements with well characterised monoenergetic and radionuclide source neutrons. Using these data, measurements with a BS set in an unknown field will allow information on $\varphi(E)$ to be extracted.

Neutron spectra are usually represented as an array, where element φ_j is the fluence in group j extending from energy E_j to E_{j+1}, and the measured reading is then given by

$$M_i = \sum_{j=1}^{n} R_{ij}\varphi_j, \tag{1.8}$$

where R_{ij} represents $R_i(E)$ averaged over group j. The above equation is an approximation to Eq. (1.7), the degree of approximation decreasing as the number of groups, n, increases. If there are m spheres, Eq. (1.8) represents a set of m linear equations, and if $m \geqslant n$ they can be solved, using least-squares methods, to provide values of φ_j. However, because m is usually small, of the order of 10, the solution may provide a poor representation of the spectrum with important features 'washed' out by the broad energy groups. Spectra are therefore usually represented by an array with $n>m$, which means that Eq. (1.8) can only be solved for φ_j either by a trial-and-error process, or by using additional a priori information [6].

Most often, a certain program is used to calculate the sensitivity matrix based on experimental measurement data of reference neutron fields. However, the absence of strictly monoenergetic neutron reference fields makes it difficult to reliably determine the sensitivities for various spheres in the specified energy ranges. A comparison of the results of using different methods for determining the sensitivity matrix to the same Bonner systems shows certain differences between them, which confirms the existence of uncertainty in the methods themselves for obtaining these matrices.

A large number of spectra have been measured with BSs. Those made prior to the mid-1990s. Fluence rates have varied from very low, i.e. natural background (about 10^{-2} cm^{-2} s^{-1}), to the high intensities (up to 10^4 cm^{-2} s^{-1}) found within the containment of reactors. The spectra vary in hardness from mean energies of less than 10 keV around reactors, to about 50 MeV at high-energy accelerators. Measurement sites have ranged from the very harsh conditions within PWR containment to green-field sites. They have also included aircraft interiors, fuel reprocessing plants, mountain tops, areas around nuclear fuel transport flasks, and radionuclide source fabrication plants. For all of these a BS set has been found well suited to measure the spectrum. The preceding sections have noted some advantages and disadvantages of BS systems. These are summarised in Table 1.

Table 1 – Summary of the advantageous features and drawbacks of BS systems

Characteristic	Verdict	Comment
Energy resolution	Poor	Restricted by similarity of response functions available
Energy range	Excellent	The only spectrometer presently available which will cover the energy range from thermal to the GeV region
Sensitivity	Good	High sensitivity by comparison with other neutron spectrometers, and can be varied by changing the thermal sensor
Operation	Simple but lengthy	Making measurements is simple, with no really complex electronics, but it can be time consuming
Angular response	Isotropic	Do not need to know the direction of the neutron field. Ideal for deriving ambient dose equivalent, but provides no angular data for deriving effective dose
Spectrum unfolding	Potential for errors	Complex unfolding code required, and the under-determined problem means that any solution is not unique; significant errors are possible
Photon discrimination	Good	By the choice of an appropriate sensor systems can be made insensitive, even to intense photon fields

1.5 Time-of-flight and gravimetric methods

The techniques proposed to detect the neutrons usually require the detection of a secondary recoiling nucleus in a scintillator (or other type of detector) to indicate the rare collision of a neutron with a nucleus. This is the same basic technique, in this case detection of a recoil proton that was used by Chadwick in the 1930 s to discover and identify the neutron and determine it is mass. It is primary technique still used today for detection of fast neutron, which typically involves the use of a hydrogen based organic plastic or liquid scintillator coupled to a photo-multiplier tube. The light output from such scintillators is a function of the cross section and nuclear kinematics of the n + nucleus collision. With the exception of deuterated scintillators, the scintillator signal does not necessarily produce a distinct peak in the scintillator spectrum directly related to the incident neutron energy. Instead neutron time-of-flight (TOF) often must be utilized to determine the neutron energy, which requires generation of a prompt start signal from the nuclear source emitting the neutrons.

This method is based on measuring the time t required for a neutron to overcome the distance L from the source to the detector. Here L is called the flight base of the spectrometer. It is already easy to find the kinetic energy of a neutron by speed. To measure time t with a known flight base L, it is necessary to know the moment of the neutron's exit from the source (the moment of start) and the moment of its arrival at the detector (the moment of finish). The schematic diagram of the time-of-flight method is shown in the figure 8.

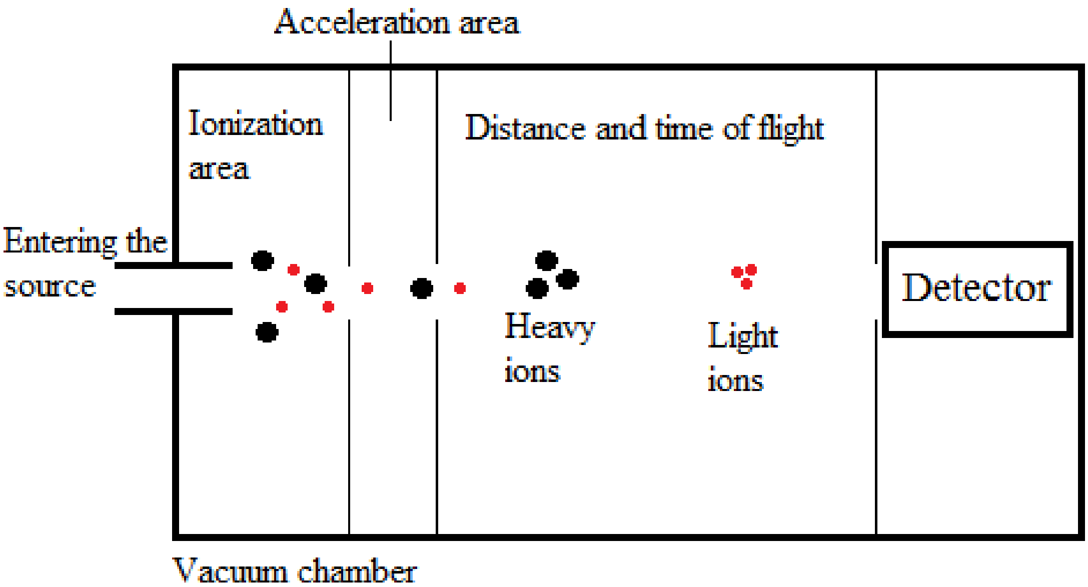

Figure 1.6 – Time-of-flight mass spectrometer diagram

The time t it takes the ions to travel the distance L determines their speed $V = L/t$. This information, combined with the measurement of the energy of the particle, gives the mass (nonrelativistically):

$$M = \frac{2Et^2}{L^2} \tag{1.9}$$

The errors in determining the mass come from uncertainty in energy, ΔE, in time, Δt, and in length of the flight path, ΔL. The mass resolution is then given by

$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta E}{E}\right)^2 + \left(\frac{2\Delta t}{t}\right)^2 + \left(\frac{2\Delta L}{L}\right)^2} \tag{1.10}$$

Usually, the system is designed in such a way that AL/L is negligible compared to the other two terms of Eq. 1.10. Assuming that this is the case, consider the sources of uncertainty in energy and time.

The time t it takes the particle to travel the distance L is the difference between a *START* and a *STOP* signal (Figure 1.7). The *STOP* signal is generated by the detector, which measures the energy of the ion. This detector is usually a surface-barrier detector. The *START* signal is generated by a transmission counter, also called the *SE* detector. The ion loses a tiny fraction of its energy going through the *START* detector [7].

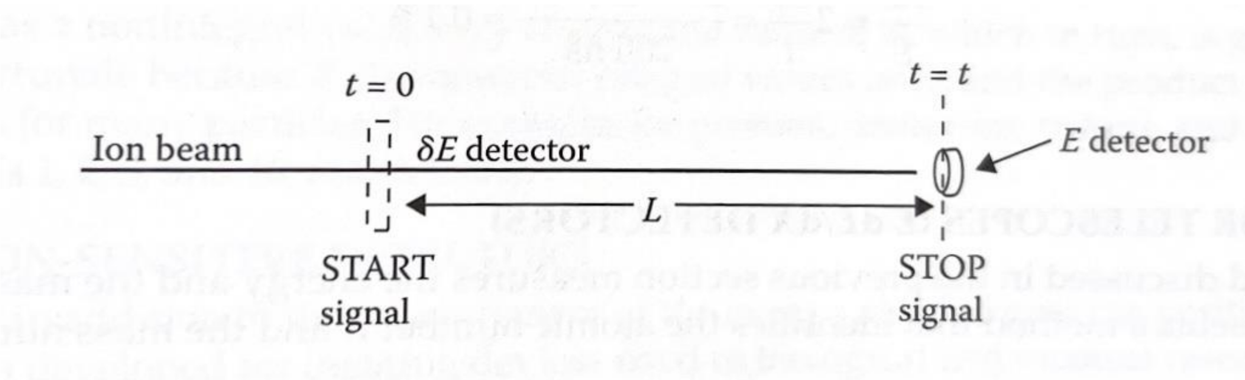

Figure 1.7 – The principle of time-of-flight for the determination of the mass of heavy ions

The mass of the neutron is known (to within 3 keV), and energy resolution as good as 0.1% has been achieved.

In a TOF measurement, one determines the speed of the neutron u from the time t it takes to travel a flight path of length L. The kinetic energy of the neutron is given by

$$E = Mc^2\left(\frac{1}{\sqrt{1-\beta^2}} - 1\right) = Mc^2\left(\frac{1}{\sqrt{1-L^2/c^2t^2}} - 1\right), \tag{1.11}$$

where Mc^2 = 939.552 MeV = rest mass energy of the neutron. The nonrelativistic equation is the familiar one,

$$E_{NR} = \frac{1}{2}Mv^2 = \frac{1}{2}M\frac{L^2}{t^2} \tag{1.12}$$

The moment of the finish coincides with the moment of detection of the neutron, and it is easy to determine, while the moment of the start of the neutron remains unknown. To get around this difficulty, a pulsed neutron source is used, in which neutrons are emitted for a very short moment of time, which is clearly fixed. A pulsed neutron source is created by two methods. In the first of them, the neutron flux from a continuous source (which serves as a nuclear reactor) is interrupted by a high-speed mechanical shutter.

The second method consists in the fact that a beam of accelerated charged particles is deflected for a short time to a specific target, during the bombardment of which nuclear reactions occur, as a result of which neutrons are emitted. These secondary neutrons are used.

A third method of obtaining powerful pulsed neutron sources is also known – using pulsed nuclear reactors. One of these reactors, the IBR-30 (pulse fast reactor), was built in Dubna.

An example of a time–of-flight spectrometer is the TOF-spectrometer Gneis.

There is another direct method of measuring the neutron velocity – the gravitational method, which uses a source of continuous neutron radiation (nuclear reactor). Its essence consists in using the curvature of the trajectories of neutrons in a long vacuumed channel under the influence of gravity of the Earth (Figure 1.8). Since neutrons flying out of the source, under the influence of gravity, move along parabolic trajectories corresponding to certain energies, the creation of conditions for the separation of one trajectory will lead to monochromatization of neutrons. To implement this condition, three collimators with narrow horizontal slits are installed on the path of neutron movement (the first near the neutron source, the second at the apogee of the trajectory and the third at the end of the flight base) [8].

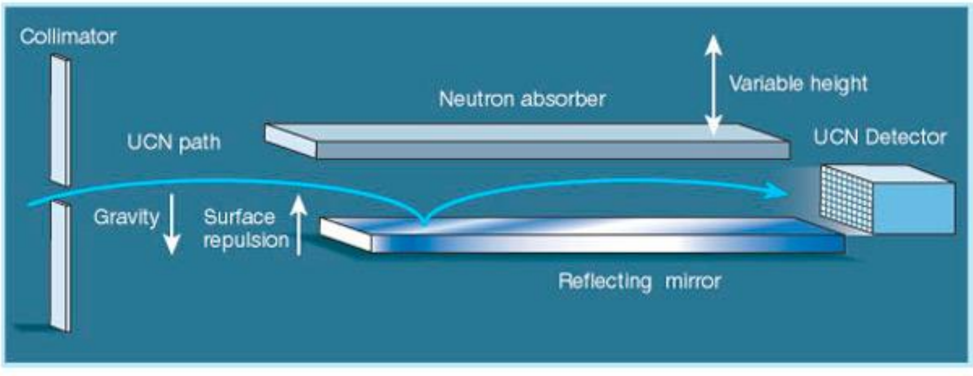

Figure 1.8 – Scheme of an experiment to observe the quantum energy levels of neutrons in the gravitational field of the Earth

Neutrons fly out into the narrow gap between the plate and the absorber and, jumping up several times, reach the neutron counter. If the height of the jumps is a fraction of a millimeter, these jumps are no longer described by classical, but by quantum physics. By measuring the neutron flux depending on the gap width, it is possible to detect the quantization of the neutron motion vertically.

Methods for measuring the neutron velocity are very expensive, and the equipment used for these methods is quite cumbersome and would not fit in the physical hall of the reactor. Moreover, a point source is needed to measure the neutron velocity, and a reactor is not one.

1.6 Registration method based on elastic neutron scattering on hydrogen nuclei

Some methods of fast neutron detection are based on elastic neutron scattering, since neutron deceleration mainly occurs through elastic scattering.

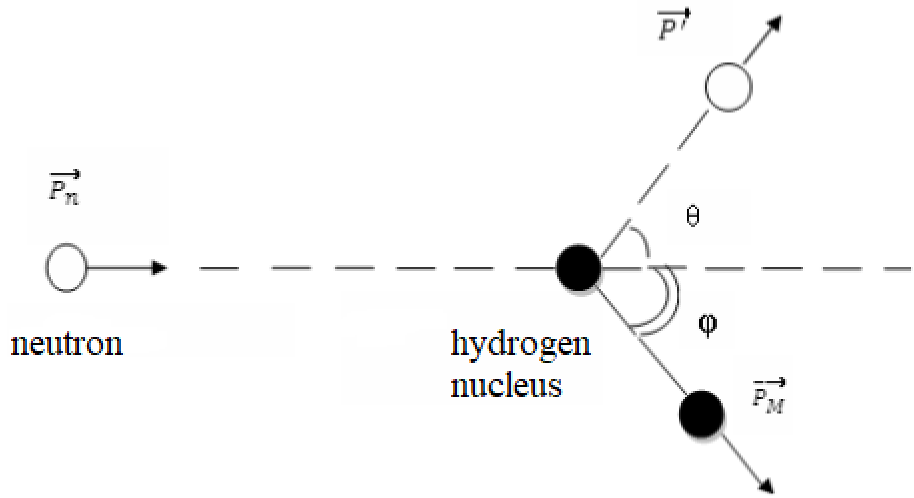

Figure 1.9 – Elastic neutron scattering kinematics: E and p are the energy and momentum of the neutron before the collision; E' and p' are the energy and momentum of the neutron after the collision; E_m and p_m are the energy and momentum of the nucleus after the collision; θ is the angle of neutron scattering; ϕ is the recoil angle of the nucleus with mass M

There is a registration method based on elastic neutron scattering on hydrogen nuclei.

The method uses a detector on an organic scintillator with a photoelectronic multiplier. It uses special filtering organisms for mathematical processing of incoming signals.

To separate the detector signals generated as a result of neutron registration, the method of digital identification by the shape of the pulse is used. The continuous (analog) signal coming from the detector is subjected to time sampling and level quantization (digitization), i.e. it is presented in digital form and stored. The resulting data array is processed according to a special algorithm, the result of which is to determine the type of particle that has entered the detector. Further analysis can be performed an unlimited number of times using various algorithms.

The spectrometer measures the energy distribution of the neutron radiation flux density in the energy range of 0.1–15 MeV.

The SDFM-1608SN dosimeter spectrometer, which works according to the described method, is at the certification stage.

In order to use this dosimeter in industry, it must be certified. For this purpose, measurements were carried out in the fields of the PIAF laser accelerator at certain neutron energies [6].

The measurement results confirm the ability of the dosimeter spectrometer to measure the energy dependences of the absolute neutron flux density in a wide energy range.

1.7 Analysis of neutron spectrometry methods

The descriptions given in sections 2.2 – 2.6 allow us to conclude that none of the modern methods of neutron spectrometry can meet all the requirements of measurements at a research nuclear reactor.

Activation analysis method: limited in the set of available and easy-to-use indicators; limited when used in both small and large radiation fluxes; not operational.

Recoil proton registration (with the exception of the method mentioned in clause 2.6, based on the analysis of the recoil proton pulse shape) does not have a direct relationship between the amplitude of the signal recorded by the detector and the neutron energy. Therefore, it is used mainly in dosimetry, to compare the incoming signal with the signal from an exemplary neutron source, which usually has a different (different from the measured) spectrum [10].

Time-of-flight and gravimetric methods are expensive and cumbersome. They are usually applicable only to pulsed neutron sources.

The Banner method (multi-ball) does not show the spectrum immediately. The restoration of the spectrum requires a lot of time to process the initial experimental data.

The method of peak shape analysis in elastic scattering is applicable in the neutron energy range from 100 keV. The permissible load of the measuring channel is not large (within 105 imp/s). In addition, the method is not certified and is under experimental verification [9].

As a result of the analysis of the advantages and disadvantages of various methods of measuring neutron spectra, it was decided to use the Bonner method and the analysis of the waveform with elastic neutron scattering for experimental work at the IRT-T reactor. The main advantage of both methods is the mobility of the equipment used in them.

ASSIGNMENT FOR THE DIPLOMA PROJECT SECTION «FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING»

Student:

Group	Name
0АМ1Ф	Ekaterina I. Serebryakova

School	School of Nuclear Science and Engineering	**Department**	Division for Nuclear-Fuel Cycle
Educational level	Master	**Specialization**	14.04.02 Nuclear Physics and Technology

Initial data for the section "Financial Management, Resource Efficiency and Resource Saving":	
1. The cost of scientific research resources: material, technical, energy, financial, informational and human	*Budget of research not higher than 225698.35 rubles, salaries of executors not higher than 109754 rubles*
2. Norms and standards for spending resources	*Supervisor' salary – 51090 rubles per month;engineer' salary – 26083.2 rubles per month*
3. The system of taxation used, tax rates, volumes of payments, discounts and loans	*Coefficient of incentive bonuses 0 %, coefficient of incentives for the manager for conscientious work activity 0 %; contributions for social funds are 27.1 % totally*
Problems to research, calculate and describe:	
1. Assessment of the commercial potential of engineeringsolutions	*Comparison of the possible engineer solutions*
2. Planning of research and constructing process and making schedule for all periods of the project	*Calendar plan of the project*
3. Requirement for investments	*Cost calculation*
4. Budgeting an engineering project	*Creation of the project budget*
5. Calculation of resource, financial, social, budgetary efficiency of an engineering project and potential risks	*List of resource requirements*
Graphic materials	
1. SWOT matrix *2. Plan of investments. The budget for scientific and technical research* *3. Project Efficiency indicators*	

Assignment date	31.01.2023

Consultant:

Position	Name	Academic degree	Signature	Date
Associate Professor Division for Social Sciencesand Humanities School of Core Engineering Education	Ekaterina V. Menshikova	PhD		

Student:

Group	Name	Signature	Date
0АМ1Ф	Ekaterina I. Serebryakova		

4 Financial management, resource efficiency and resource saving

The purpose of this section discusses the issues of competitiveness, resource efficiency and resource saving, as well as financial costs regarding the object to study of Master's thesis. Competitiveness analysis is carried out for this purpose. SWOT analysis helps to identify strengths, weaknesses, opportunities and threats associated with the project, and give an idea of working with them in each particular case. For the development of the project requires funds that go to the salaries of project participants and necessary equipment, a complete list is given in the relevant section. The calculation of resource efficiency indicator helps to make a final assessment of the technical decision on individual criteria and in general.

In this work, the study of neutron radiation fields behind the protection of the IRT-T reactor is carried out. The article presents the results of measuring the spectral characteristics of the neutron fields of the reactor's physical hall using two instruments.

This work is practical and requires large expenditures on spectrometric equipment.

4.1 Potential consumers of the research results

To analyze the consumers of the research results, it is necessary to segment the market.

The target market of the studied spectrometric devices is the market, commercial and budget enterprises using nuclear energy, since managers are interested in radiation safety, and therefore they will be interested in these spectrometric devices. The category of consumers for spectrometric devices are commercial enterprises. In accordance with the segmentation criteria, it can be said that the location of consumers are enterprises with neutron sources. These are research nuclear reactors, nuclear power plants, accelerator installations, medical institutions using neutron fluxes in their practice, educational institutions containing neutron sources. It is possible to segment the market to improve radiation safety using new spectrometric devices (Table 4.1).

Table 4.1 – A market segmentation map showing ways to improve radiation safety.

		Types of ways to improve radiation safety				
		Neutron dosimetric equipment	Education and professional training in the use of neutron dosimetric equipment	Providing the methodology of the research program	Development of protection against neutron radiation	Code of Conduct in the field of Radiation Safety
Company	Nuclear installations					
	Radiological facility					
	Educational institutions					

Firm A

The segmentation map shows which niches in the radiation safety market are not occupied by competitors or where the level of competition is low. As a rule, two or three segments are selected, to which the maximum efforts and resources of the enterprise are directed. As a rule, segments with similar characteristics are selected, which form the target market.

4.2 Competitiveness analysis of technical solutions

Analysis of competitive technical solutions in terms of resource efficiency and resource saving allows to evaluate the comparative effectiveness of scientific developmental model. A scorecard is used to conduct this analysis. First of all, it is necessary to analyze possible technical solutions and choose the best one based on the considered technical and economic criteria.

Evaluation map analysis presented in Table 7. The position of research and competitors is evaluated for each indicator by five-point scale, where 1 is the weakest position and 5 is the strongest.

To date, there are a number of known methods of neutron spectrometry that somehow do not meet all the requirements of radiation safety or are not suitable for measurements at a research reactor. Each method is good in one or two aspects. Therefore, it is proposed to compare the method studied in this work with other known methods of neutron spectrometry:

1) methods based on measuring the energy of charged particles obtained in neutron-induced nuclear reactions;

2) methods in which the neutron velocity is measured;

3) threshold methods in which the minimum neutron energy is shown as the appearance of neutron-induced effects, such as radioactivity, gamma radiation;

4) methods in which the energy distribution of neutrons is determined from data from detectors (or detector configurations) that differ in the energy dependence of their sensitivity to neutrons.

The weights of indicators determined in the amount should be 1. Analysis of competitive technical solutions is determined by the formula:

$$C = \sum P_i \cdot W_i, \tag{4.1}$$

where C – the competitiveness of research or a competitor;

W_i – criterion weight;

P_i – point of i-th criteria.

Evaluation map analysis presented in Table 4.2 will be used to assess the competitiveness of the study, where C_n is new developed method of neutron spectrometry, C_p is cumulative neutron spectrometry methods that have been used in the past.

Table 4.2 – Evaluation card for comparison of competitive technical solutions

Evaluation criteria	**Criterion weight**	**Points**		**Competitiveness** Taking into account weight coefficients	
		P_n	P_p	C_n	C_p
1	2	3	4	6	7
Technical criteria for evaluating resource efficiency					
1. Increasing radiation protection	0.1	5	4	0.5	0.4

2. Ease of use of the method	0.1	5	3	0.5	0.3
3. The quality of the results obtained	0.1	5	4	0.5	0.4
4. Measurement time	0.1	5	3	0.5	0.3
5. Easy of calculation	0.1	5	3	0.5	0.2
Economic criteria for performance evaluation					
1. Development cost	0.1	3	4	0.3	0.4
2. Market penetration rate	0.1	4	3	0.4	0.3
3. Equipment price	0.2	2	3	0.4	0.6
4. Estimated life-time	0.1	5	5	0.5	0.5
Total	1	39	32	4,1	3.4

Analyzing the results, we can conclude that the new method of neutron spectrometry by technical criteria is much superior to the old methods of neutron spectrometry. However, the new method is quite expensive and insufficiently adapted to all market segments, since it is only at the stage of certification and experiments.

4.3 SWOT analysis

Complex analysis solution with the greatest competitiveness is carried out with the method of the SWOT analysis: Strengths, Weaknesses, Opportunities and Threats (Table 4.3). The analysis has several stages. The first stage consists of describing the strengths and weaknesses of the project, identifying opportunities and threats to the project that have emerged or may appear in it is external environment. The second stage consist of identifying the compatibility of the strengths and weaknesses of the project with the external environmental conditions. This compatibility or incompatibility should help to identify what strategic changes are needed.

The SWOT analysis has shown that the most profitable strategy is based on weaknesses and opportunities, where the neutron spectrometry method should be registered and tested for widespread use at nuclear facilities, but at the same time do not forget about weaknesses and take actions that eliminate them [13].

Table 4.3 – SWOT analysis

	Strengths: **S1.** Mobility of neutron spectrometry equipment; **S2**. Shows the neutron spectrum in real time, no need to waste time restoring the spectrum; **S3.** Suitable energy spectrum for many nuclear installations.	**Weaknesses:** **W1.** The UNSD-15 dosimeter spectrometer is not yet a certified spectrometric device; **W2.** Expensive spectrometric equipment; **W3.** Limited number of spectrometers (several pieces throughout Russia).
Opportunities: **O1.** Certification of the method and implementation at the international industrial level; **O2.** Expansion of production of a new neutron spectrometer; **O3.** Financing the development and creation of new neutron spectrometers at the international level.	Development of a neutron spectrometry method that can be used in relation to nuclear installations and accepted by governing bodies as recommended for use.	The developed method of neutron spectrometry should be registered before use on real facilities using atomic energy and tested on hypothetical facilities.
Threats: **T1.** Inability to pass the certification of the device; **T2.** Impossibility of financing scientific research by the state; **T3.** Restrictions on technology exports	Development of guidelines for measuring neutron spectra by a new method and improvement of radiation safety culture.	To develop a neutron spectrometry method that can be used in relation to real nuclear power facilities, which has the potential for international implementation and long-term research due to timely updating.

4.4 Assessment of the project's readiness for commercialization

To assess the degree of readiness of scientific development for commercialization, a special form was set (Table 4.4), taking into account the degree of development of the project for commercialization and the competence of the developer of the scientific project.

Table 4.4 – Assessment from for the degree of readiness of a scientific project for commercialization

№	Description	The degree of the project's elaboration	The level of the researcher's knowledge
1	The existing scientific and technical reserve is determined	4	5
2	Promising areas of commercialization of the scientific and technical reserve are identified	5	5
3	Industries and technologies (goods, services) to be offered on the market are identified	5	5
4	The commodity form of the scientific and technical reserve for supply at the market is defined	5	5
5	Authors have been identified and their rights have been protected	5	5
6	An assessment of the value of intellectual property was carried out	4	4
7	Marketing research of sales markets was carried out	4	4
8	A business plan for the commercialization of scientific development has been developed	4	3
9	The ways of promoting scientific development to the market are determined	5	5
10	A strategy for the implementation of scientific development has been developed	5	4
11	The questions of international cooperation and access to the foreign market areinvestigated	2	2
12	The ways to receive state support and benefits are analyzed	3	3
13	The sources of financing the commercialization of scientific development are found	3	3
14	The team for the commercialization of scientific development is formed	5	5
15	The mechanism of implementation of the scientific project has been worked out	4	4
	TOTAL SUM OF POINTS	63	62

When analyzing the table above, each indicator is evaluated on a five-point scale. At the same time, the measurement system for each direction (the degree of elaboration of the scientific project, the level of available knowledge of the developer) is different. So, when assessing the degree of elaboration of a scientific project, 1 point means not the elaboration of the project, 2 points. a-weak elaboration, 3 points-performed, but not sure of the quality, 4 points – performed qualitatively, 5 points-there is a positive opinion of an independent expert. To assess the level of knowledge available to the developer, the points system takes the following form: 1 – I do not know or know little, 2 – in the scopeof theoretical knowledge, 3 – I know the theory and practical examples of application, 4 –I know the theory and independently perform, 5 – I know the theory, perform and can advise.

The assessment of the readiness of a scientific project for commercialization (or the level of existing knowledge of the developer) is determined by the formula:

$$P_{sum} = \sum P_i, \tag{4.2}$$

where P_{sum} is the total number of points for each direction;

P_i, – the score on the i-th indicator.

The value of P_{sum} allows us to speak about the degree of readiness of scientific development and its developer for commercialization. So, the Sum value is 63 and 62, the development of a new method of neutron spectrometry to improve the culture of radiation safety is considered promising, and the developer's knowledge is sufficient for its successful commercialization.

Readiness for implementation and commercialization of the developed is at a fairly high level. To increase this level, it is necessary to register the rights of authors and more precisely work out a plan to attract investment in scientific development.

4.5 Methods of commercialization

The goal of this section of the master's thesis is to choose the method of commercialization of the object of research and to justify its feasibility. In order to do this,it is necessary to navigate in the possible options.

The following methods of commercialization of scientific developments have been selected for the introduction of a new method of spectrometry.

1. Trade in patent licenses, i.e. the transfer to third parties of the right to

use intellectual property objects on a license basis. At the same time, the patent legislation distinguishes the types of licenses: non-exclusive (simple), exclusive, full licenses, sub- licenses, options. It is much cheaper and easier to obtain a license or a patent for a developed model than to organize your own commercial enterprise. Implementation of usage models in identified enterprises is available through patent license trading.

2. Transfer of know-how, i.e. the provision by the owner of the know-how of the opportunity to use it by another person, carried out by disclosing the know-how. It is also easier and cheaper to commercialize than franchising or engineering. Does not require the involvement of large human resources, can be implemented in a short time.

3. Transfer of intellectual property to the authorized capital of the enterprise.

The registered intellectual property can be easily transferred to an interested client, without the need to organize the accompanying process of using the spectrometer. However, for such a method, it is necessary to bring the use of the spectrometer into an understandable and accessible form for use by a person who is not familiar with the spectrometer. It can be software or program code.

The selected commercialization methods will help to promote the developed method of neutron spectrometry to improve the culture of radiation safety.

4.6 Project Initiation

The initiation progress group consists of processes that are performed to define a new project or a new phase of an existing one. In the initiation processes, the initial purpose and content are determined and the initial financial resource are fixed. The internal and external stakeholders of the project who will interact and influence the overall result of the research project and determined (Table 4.5).

Table 4.5 – Stakeholders of the project

Project stakeholders	Stakeholder expectations
Nuclear industry facilities: research reactors, nuclear power plants	A new method of neutron spectrometry, which will increase the level of radiation safety culture at nuclear facilities.

Table 4.6 shows the goals and results that will be set and achieved during the workon this project.

Table 4.6 – Purpose and results of the project

Purpose of project:	To conduct research and testing of new spectrometric equipment, followed by certification, to improve the culture of radiation safety.
Expected results of the project:	The result of this project was the study and testing of mobile equipment for neutron spectrometry for further use on an industrial scale.
Criteria for acceptance of theproject results:	The speed of the dosimetric equipment, the accuracy of the results obtained, the energy range and the mobility of the equipment are evaluated.
Requirements for the projectresults:	Structured guidelines that provide all the information necessary for conducting and required for the use of spectrometric equipment on real facilities.
	Spectrometric equipment must be certified according to all requirements.

4.6.1 The organizational structure of the project

It is necessary to solve some questions: who will be part of the working group of this project, determine the role of each participant in this project, and prescribe the functions of the participants and their number of labor hours in the project. This information is presented in Table 4.7.

Table 4.7 – Structure of the project

№	**Participant**	**Role in project**	**Functions**	**Labor time, hours**
1	Maxim E. Silaev, Associate Professor	Supervisor	Creation of a work and management of the research process.	132
2	Ekaterina I. Serebryakova, Student	Engineer	Calculations, graphing, analysis of the results.	546

4.6.2 Project limitation

Project limitations are all factors that can be as a restriction on the degree of freedom of the project team members. This information is presented in Table 4.8.

Table 4.8 – Project limitations

Factors	**Limitations / Assumptions**
3.1. Project's budget, rub	6699925
3.1.1. Source of financing	Tomsk Polytechnic University
3.2. Project timeline	15.03.2023-06.06.2023
3.2.1. Date of approval of plan of project	25.03.2023
3.2.2. Completion date	06.06.2023

4.6.3 Project Schedule

As part of planning a science project, it is needed to build a project timeline and aGantt Chart (Table 4.10).

Table 4.9 – Project Schedule

Job title	**Duration, working days**	**Start date**	**Date of completion**	**Participants**
Goal and objectives setting	3	15.03.2023	17.03.2023	S
Special literature selection and studying	5	17.03.2023	23.03.2023	E
Literature discussion	2	27.03.2023	28.03.2023	S, E
Conducting dosimetric measurements in the physical hall of the research reactor by method No. 1	3	28.03.2023	30.03.2023	S, E
Conducting dosimetric measurements in the physical hall of the research reactor by method No. 2	5	31.03.2023	06.04.2023	S, E
Construction of neutron radiation spectra	11	07.04.2023	21.04.2023	E
Analysis of methods	6	21.04.2023	01.05.2023	E
Writing a research program	11	02.05.2023	12.05.2023	E
Preparing an explanatory note	11	15.05.2023	29.05.2023	E
Summarizing	5	30.05.2023	06.06.2023	S, E
Total sum:	62			

A Gantt chart, or harmonogram, is a type of bar chart that illustrates a project schedule. This chart lists the tasks to be performed on the vertical axis, and time intervalson the horizontal axis. The width of the horizontal bars in the graph shows the duration ofeach activity.

Table 4.10 – A Gantt chart

№	Activities	Participants	T_c, days	Duration of project											
				March			April			May			June		
				1	2	3	1	2	3	1	2	3	1	2	3
1	Goal and objectives setting	S	3												
2	Special literature selection and studying	E	5												
3	Literature discussion	S, E	2												
4	Conducting dosimetric measurements in the physical hall of the research reactor by method No. 1	S, E	3												
5	Conducting dosimetric measurements in the physical hall of the research reactor by method No. 2	S, E	5												
6	Construction of neutron radiation spectra	E	11												
7	Analysis of methods	E	6												
8	Writing a research program	E	11												
9	Preparing an explanatory note	E	11												
10	Summarizing	S, E	5												

Supervisor (S) □ ;

Engineer (E) – ;

4.7 Scientific and technical research budget

The amount of costs associated with the implementation of this work is the basis for the formation of the project budget. This budget will be presented as the lower limit of project costs when forming a contract with the customer.

To form the final cost value, all calculated costs for individual items related to themanager and the student summed.

In the process of budgeting, the following grouping of costs by items is used:

– Material costs of scientific and technical research;

– Costs of special equipment for scientific work (Depreciation of equipment usedfor design);

– Basic salary;

– Additional salary;

– Labor tax;

– Overhead.

4.7.1 Costs of special equipment

This point includes the costs associated with the acquirement of special equipment (instruments, stands, devices and mechanisms) necessary to carry out work on a specific topic.

Calculation of the depreciation. Depreciation is not charged if an equipment cost is less than 40 thousand rubles, its cost is taken into account in full.

It is needed to calculate depreciation:

$$A = \frac{C_{init} \times H_a}{100}, \tag{4.3}$$

where A – annual amount of depreciation;

C_{init} – initial cost of the equipment;

$H_a = \frac{1}{T} \times 100\%$ – rate of depreciation;

T_{ex} – life expectancy.

Calculate depreciation on used equipment.

The life expectancy (T) of the dosimeters is 7 years (2555 working days).

Initial cost (C_{init}) of the Neutron and gamma radiation spectrometer-dosimeter UNSD-15 is 6000000 rub.

Initial cost ($C_{init)}$ of the Dosimeter-radiometer AT1117M is 450000 rub.

Depreciation for UNSD-15:

$$A = \frac{6000000 \times 0{,}0391}{100} = 2346, \tag{4.4}$$

Depreciation for AT1117M:

$$A = \frac{450000 \times 0{,}0391}{100} = 175.95, \tag{4.5}$$

The dosimetric equipment was used for 3 working days.

The life expectancy (T) of the personal computer is 5 years (1825 days).

Depreciation for Personal computer:

$$A = \frac{50000 \times 0{,}0548}{100} = 27.4, \tag{4.6}$$

The personal computer was used for 84 days.

Table 4.11 – Depreciation of special equipment and software

№	Equipment identification	Quantity of equipment	Total cost of equipment, rub.	Life expectancy, year	Time of usage, days	Depreciation of the duration of the project, rub.
1	Personal computer	1	50000	5	62	1698.8
2	UNSD-15	1	6000000	7	3	7038
3	AT1117M	1	450000	7	3	527.85
Total						9264.65

4.7.2 Basic salary

The point includes the basic salary of participants directly involved in the implementation of work on this research. The value of salary costs is determined based on the labor intensity of the work performed and the current salary system.

The basic salary is calculated according to the formula:

$$S_b = S_d \times T_w, \tag{4.7}$$

where S_b – basic salary per participant;

T_w – the duration of the work performed by the scientific and technical worker,working days;

S_d – the average daily salary is calculated by the formula:

$$S_d = \frac{S_m \times M}{F_v}, \qquad (4.8)$$

where S_m – monthly salary of a participant, rub.;

M – the number of months of work without leave during the year: at holiday in 48days, M = 11.2 month, 6 days per week;

F_v – valid annual fund of working time of scientific and technical personnel(251 days).

Table 4.12 – The valid annual fund of working time

Working time indicators	**Days**
Calendar number of days	365
The number of non-working days –– weekends –– holidays	 52 14
Loss of working time ––vacation ––isolation period ––sick absence	48
The valid annual fund of working time	251

Monthly salary is calculated by formula:

$$S_{month} = S_{base} \times (k_{premium} + k_{bonus}) \times k_{reg}, \qquad (4.9)$$

where S_{base} – base salary, rubles;

$k_{premium}$ – premium rate;k_{bonus} – bonus rate;

k_{reg} – regional rate.

Table 4.13 – Calculation of the base salaries

Performers	**S_{base}, rub.**	**$k_{premium}$**	**k_{bonus}**	**k_{reg}**	**S_{month}, rub.**	**S_d, rub.**	**T_p, work days (from table 6)**	**W_{base}, rub.**
Supervisor	39300	–	–	1.3	51090	2280.8	18	41054.4
Engineer	20064				26083.2	1164.4	59	68699.6

4.7.3 Labor tax

Tax to extra-budgetary funds are compulsory according to the norms established by the legislation of the Russian Federation to the state insurance (SIF), pension fund (PF)and medical insurance (FCMIF) from the cost of workers.

Payment to extra-budgetary funds is determined of the formula:

$$P_{social} = k_b \times (W_{base} + W_{add}), \quad (4.10)$$

where k_b – coefficient of deductions for labor tax.

In accordance with Federal law of July 24, 2009 № 212-FL, the amount of insurance contributions is set at 30 %. Institutions conducting educational and scientific activities have rate – 27.1 %.

Table 4.14 – Labor tax

	Project leader	Engineer
Coefficient of deductions	0.271	
Salary (basic and additional), rubles	41054.4	68699.6
Labor tax, rubles	11125.7	18617.6

4.7.4 Overhead costs

Overhead costs include other management and maintenance costs that can be allocated directly to the project. In addition, this includes expenses for the maintenance, operation and repair of equipment, production tools and equipment, buildings, structures,etc.

Overhead costs account from 30 % to 90 % of the amount of base and additionalsalary of employees.

Overhead is calculated according to the formula:

$$C_{ov} = k_{ov} \cdot (W_{base} + W_{add}), \quad (4.11)$$

where k_{ov} – overhead rate.

Table 4.15 – Overhead

	Project leader	Engineer
Overhead rate	0.7	
Salary, rubles	41054.4	68699.6
Overhead, rubles	28738.1	48089.7

4.7.5 Other direct costs

Energy costs for equipment are calculated by the formula:

$$C = P_{e1} \cdot P \cdot F_{eq}, \quad (4.12)$$

where P_{e1} – power rates (5.8 rubles per 1 kWh);

P – power of equipment, kW;

F_{eq} – equipment usage time, hours.

Table 4.16 – Other direct costs

Name	Work time, h	Electric	Price per unit, rub	Energy costs, rub
1. Computer	400	0.045 kWh	5.8	104.4
2. UNSD-15	8	0.045 kWh		2.1
3. AT1117M	8	0.045 kWh		2.1
Total:				108.6

4.7.6 Formation of budget costs

Determining the budget for the scientific research is given in table 4.17.

Table 4.17 – Items expenses grouping

Name	Cost, rubles
1. Material costs	0
2. Equipment costs	9264.65
3. Basic salary	109754
4. Additional salary	0
5. Labor tax	29743.3
6. Overhead	76827.8
7. Other direct costs	108.6
Total planned costs	225698.35

4.8 Evaluation of the comparative effectiveness of the project

Determination of efficiency is based on the calculation of the integral indicator of the efficiency of scientific research. Its finding is associated with the determination of two weighted averages: financial efficiency and resource efficiency.

An integral indicator of the financial efficiency of a scientific research is obtained in assessing the budget of costs of three (or more) variants of the implementation of a scientific research (Table 4.18). For this, the largest integral indicator of the implementation of a technical problem is taken as the basis of the calculation (as the denominator), with which the financial values for all execution options are correlated.

Integral financial indicator is determined in the formula:

$$I_f^d = \frac{F_i}{F_{max}}, \quad (4.13)$$

where I_f^d– integral financial indicator of current project;

F_{max} – maximum cost of execution of a research project (including analogs).

The resulting value of the integral financial indicator of development reflects the corresponding numerical increase in the budget of development costs in times (a value greater than one), or the corresponding numerical reduction in the cost of development intimes (a value less than one, but higher than zero).

The integral indicator of the resource efficiency of the variants of the object of research can be defined as follows:

$$I_m^a = \sum_{i=1}^{n} a_i b_i^a; \; I_m^p = \sum_{i=1}^{n} a_i b_i^p, \quad (4.14)$$

where I_m^a is an integral indicator of resource efficiency of options;

a_i – the weight coefficient of the i-th parameter;

b_i^a, b_i^p – the score of the i-th parameter for the analog and development, set by an expert method on the selected rating scale;

n – the number of comparison parameters.

The calculation of the integral resource efficiency indicator is presented in theform of table 4.18.

Table 4.18 – Evaluation of the performance of the project.

Evaluation criteria	**Criterion weight**	**Points**	
		Developed predictive model	**Available self-assessment process**
Technical criteria for evaluating resource efficiency			
1. Increasing radiation protection	0.1	5	4
2. Ease of use of the method	0.1	5	3
3. The quality of the results obtained	0.1	5	4
4. Measurement time	0.1	5	3
5. Easy of calculation	0.1	5	3
Economic criteria for performance evaluation			
1. Development cost	0.1	3	4
2. Market penetration rate	0.1	4	3

3. Equipment price	0.2	2	3
4. Estimated life-time	0.1	5	5
Total	**1**	**39**	**32**

The integral indicator of the development efficiency (I_e^a) is determined on the basis of the integral indicator of resource efficiency and the integral financial indicator using the formula:

$$I_e^p = \frac{I_m^p}{I_f^d};\ I_e^a = \frac{I_m^a}{I_f^a} \qquad (4.15)$$

Comparison of the integral indicator of the efficiency of the current project and analogs will determine the comparative efficiency the project. Comparative projectefficiency:

$$E_c = \frac{I_e^p}{I_e^a} = \frac{4.8}{2.9} \approx 1.65, \qquad (4.16)$$

where E_C is the comparative project efficiency;

I_e^p – integral indicator of project;

I_e^a – integral indicator of the analog.

Table 4.19 – Comparative project efficiency

№	Indic ator	Developed predictive model	Available self-assessment process
1	Integral financial indicator	1	0.5
2	Integral resource efficiency indicator	4.0	2.7
3	Integral efficiency indicator	4.5	2.9

Comparison of the values of integral performance indicators allows us to understandand choose a more effective solution to the technical problem from the standpoint of financial and resource efficiency.

4.9 Financial management conclusion

In this section was developed stages for design and create competitive development that meet the requirements in the field of resource efficiency and resource saving.

These stages include:

- development of a common economic project idea, formation of a projectconcept;
- organization of work on a research project;
- identification of possible research alternatives;
- research planning;
- assessing the commercial potential and prospects of scientific research from thestandpoint of resource efficiency and resource saving;
- determination of resource (resource saving), financial, budget, social andeconomic efficiency of the project.

The competitiveness analysis was also carried out, which showed that the developed method of neutron spectrometry has a number of advantages over existing methods.

The readiness for the implementation and commercialization of the developed is at a fairly high level. To increase this level, it is necessary to register the rights of authors and more precisely develop a plan to attract investment in scientific research. Possible ways of commercialization of scientific developments were also chosen.

ASSIGNMENT FOR THE DIPLOMA PROJECT SECTION
«SOCIAL RESPONSIBILITY»

Student:

Group	Name
0AM1Ф	Ekaterina I. Serebryakova

School	School of Nuclear Science and Engineering	**Department**	Division for Nuclear-Fuel Cycle
Educational level	Master	**Specialization**	14.04.02 Nuclear Physics andTechnology

<table>
<tr><td colspan="2">Initial data for the section “Social Responsibility”:</td></tr>
<tr><td>1. Description of the workplace (work area, process, mechanical equipment) for the occurrence of:
– harmful manifestations of industrial environment factors (weather conditions, harmful substances, lighting, noise, vibrations, electromagnetic fields, ionizing radiation)
– dangerous manifestations of industrial environment factors (mechanical nature, thermal nature, electrical, fire and explosive nature)
– negative impact on the environment (atmosphere, hydrosphere, lithosphere) emergency situations (technogenic, natural, environmental and social)</td><td>Horizontal experimental Channel of the IRT-T Research Nuclear Reactor</td></tr>
<tr><td colspan="2">List of issues to be researched, designed and developed:</td></tr>
<tr><td>1. Analysis of the identified harmful factors of the designed production environment in the following sequence:
– physical and chemical nature of harmfulness, its connection with the topic being developed;
– the effect of the factor on the human body;
– reduction of permissible norms with the required dimension (with reference to the relevant regulatory and technical document);
– Suggested remedies (first collective protection, then individual protective equipment)</td><td>– electromagnetic radiation;
– insufficient illumination;
– noise;
– microclimate;
– psychophysical factors;
– radiation;
– harmful substances.</td></tr>
<tr><td>2. Analysis of identified hazardous factors of the designed manufactured environment in the following sequence:
– mechanical hazards (sources, means of protection;
– thermal hazards (sources, means of protection);
– electrical safety (including static electricity, lightning protection - sources, means of protection);
– fire and explosion safety (causes, preventive measures, primary fire extinguishing means)</td><td>– electric current;
– fire hazard.</td></tr>
</table>

3. *Emergency protection:* – *list of possible emergencies at the facility;* – *choice of the most typical emergency situation;* – *development of preventive measures to prevent emergencies;* – *development of measures to improve thestability of the object to this emergency;* – *development of actions as a result of emergencies and measures to eliminate its consequences.*	– the occurrence of a fire in the workplace; – electric shock; – collapse of the ceilings of the building; – the fall of a man into the reactor pool; – depressurization of the HEC; preventive measures and procedures in case of emergencies
4. Legal and organizational issues of security: – *special (characteristic for the designed working area) legal norms of labor legislation;* – *organizational measures in the layout of the working area.*	– *SanPiN 1.2.3685-21;* – *SanPiN 2.6.1.2523-09;* – *GOST 12.1.038-82 SSBT;* – *GOST R 53692-2009;*

Assignment date	03.02.2023

Consultant:

Position	Name	Academic degree	Signature	Date
Associate Professor Division of Nuclear Fuel Cycle DivisionSchool of Nuclear Science & Engineering	Yuriy V. Perederin	PhD		

Student:

Group	Name	Signature	Date
0АМ1Ф	Ekaterina I. Serebryakova		

5 Social responsibility

5.1 Introduction

In this research work, new methods for measuring neutron field spectra near the IRT-T reactor are being developed. The testing was carried out on the basis of the experimental device Horizontal experimental channel №1.

This section discusses the dangerous and harmful factors possible during research, legal and organizational issues, as well as emergency measures.

Labor protection and safety regulations are introduced in order to prevent accidents, ensure safe working conditions for workers and are mandatory for workers, managers, engineering and technical workers.

A dangerous production factor is a production factor, the impact of which, under certain conditions, leads to injury or other sudden, sharp deterioration of health.

A harmful production factor is a production factor, the impact of which on the worker, under certain conditions, leads to illness or a decrease in working capacity.

In the room of the horizontal experimental channel, the following harmful factors were identified:

– electromagnetic radiation;

– insufficient illumination;

– noise;

– microclimate;

– psychophysical factors;

– radiation;

– harmful substances.

5.2 Legal and organization items in providing safety

According to the Labor Code of the Russian Federation [17], every employee has the right to:

– workplace that meets the requirements of labor protection;

– obtaining reliable information from the employer, relevant state bodies and public organizations about the conditions and labor protection at the workplace, the existing risk of health damage, as well as measures to protect against the effects of harmful and (or) hazardous production factors;

– refusal to perform work in case of danger to his life and health due to violation of labor protection requirements, except for the following cases;

– provision of means of individual and collective protection;

– training in safe methods and techniques of work at the expense of the employer;

– an extraordinary medical examination in accordance with medical recommendations with the preservation of his place of work and average earnings during the examination;

– guarantees and compensations established in accordance with this Code, a collective agreement, an agreement, a local regulatory act, an employment contract, if he is engaged in work with harmful and (or) dangerous working conditions.

5.3 Increased level of electromagnetic radiation

Electromagnetic radiation is a significant danger to humans compared to other harmful factors. In this case, the source of electromagnetic radiation is computer equipment (monitor and system unit). Prolonged exposure to intense electromagnetic radiation can cause increased fatigue, the appearance of heart pain, and disruption of the functions of the central nervous system. It should be noted that the heating of the processor during operation causes the production of some harmful compounds, which in turn lead to deionization of the surrounding space. The norms of electromagnetic fields generated by a PC are given in Table 5.1, in accordance with [15].

Table 5.1 – Permissible EMF levels created by PCs in the workplace

Name of parameters	Frequency range	Harmful permissible levels of electromagnetic field
Electric field strength	5 Hz – 2 kHz	25 V/m
	2 kHz – 400 kHz	2,5 V/m
Magnetic flux density	5 Hz – 2 kHz	250 nT
	2 kHz – 400 kHz	25 nT
Electrostatic potential of the video monitor screen		500 V

There are a number of recommendations, following which you can reduce the negative impact of computer technology:

1. If several computers or laptops are constantly in the same room, then they should be placed around the perimeter of the room, leaving the center free, since the sides and back of the monitor generate much more harmful radiation.

2. Turn off the computer after the end of work: the longer it works, the more radiation it generates, and releases a significant amount of harmful substances into the environment.

3. The use of a special protective film.

4. Systematic dusting, wet cleaning and the use of ionizers [15].

5.4 Insufficient illumination of the working area

Three different types of lighting are used in industrial premises [15]: natural, artificial and mixed.

Artificial lighting is used in the experimental device room. Wall lamps are used for protected incandescent lamps, designed for general or auxiliary lighting of industrial and utility rooms with the following characteristics:

– Rated voltage: 220 V, 50 Hz;

– Number and power of lamps: 1x100 W;

– Cartridge type: E27;

– Base: Plastic;

– Diffuser: silicate glass, transparent;

– Overall dimensions: 179x130x106 mm;

– Degree of protection: IP53.

A certain amount of dust may get inside the device, but this does not disrupt the operation of the device. Moisture protection ensures operation in rain conditions, splashes fall at an angle of up to 60 ° to the vertical.

To create favorable working conditions, the degree of illumination in industrial premises is normalized, the lighting norm is 300 lux [15]. The plot area is 24 m2, length 8 m, width 3 m, height 2.5 m.

The number of lamps for the workshop is determined by the formula:

$$N = \frac{E \cdot S \cdot K}{U \cdot n \cdot \Phi_{\text{п}}}, \tag{5.1}$$

where E – required illumination;

E = 75 lux;

S – room area;

S = 24 m^2;

K – the margin factor, which takes into account the decrease in illumination during operation, K = 1,5;

F– luminous flux of one lamp, Suitable standard lamp – LTB 40 Wt, F = 1400 lm;

U – utilization factor, U = 0,55;

m – number of lamps in the lamp, m = 1.

$$N = \frac{75 \cdot 24 \cdot 1{,}5}{0{,}55 \cdot 1 \cdot 1400} = 3{,}5\ pieces. \tag{5.2}$$

The estimated number of LTB 40 lamps was 3.5 pieces. In reality, the design requirements are met, 4 lamps are installed in the room of the horizontal experimental channel [15].

5.5 Noise

During the work on the experimental devices of the IRT-T, such devices and devices as gate mechanisms, as well as supply and exhaust ventilation are used, during the operation of which noise occurs. As a consequence, the constant operation of this equipment negatively affects the workers in the production room and, consequently, reduces their productivity.

The human ear recognizes mechanical vibrations with a frequency of 16 to 20,000 vibrations per second as noise. Vibrations with a frequency above 20,000 per second are in the ultrasonic region and are not perceived by the hearing organs [32].

Table 5.2 shows the permissible noise levels according to [15].

Table 5.2 – Values of the noise control unit

Sound pressure levels (Db) in octave bands with average geometric frequencies, Hz									Maximum sound level, Db
31,5	63	125	250	500	1000	2000	4000	8000	
79	63	52	45	39	35	32	30	28	55

To protect an employee from the effects of noise, it is necessary to eliminate their source or reduce its impact on people. To do this, it is necessary to carry out organizational and technical measures to protect personnel from noise:

– elimination of the cause of noise;

– rational planning of the premises;

– use of personal protective equipment (PPE) [33].

Conclusion: the influence of noise has a general negative impact on the employee, increasing his fatigue and leads to an increase in the number of mistakes made by the employee, as well as contributes to the occurrence of dangerous and potentially dangerous accidents.

The noise level in the room of the horizontal experimental device meets the requirements [15].

5.6 Deviations of microclimate indicators

The microclimate of industrial premises is the conditions of the indoor environment of the premises (combinations of temperature, humidity, air velocity) that affect the thermal state of a person and determine working capacity, health and labor productivity. To ensure the safe production of work, it is necessary to comply with the requirements of the microclimate of the working area, defined by [15]. Table 5.3 shows the optimal parameters of the microclimate of the room in which people are engaged in mental labor.

Table 5.3 – Optimal microclimate parameters in the work area

Period of the year	Air temperature, ^{0}C no more	Relative humidity of the air, %	Air velocity, m/s
Cold	22-24	15-75	no more 0,1
Warm	23-25	15-75	0-0,2

In computer rooms, daily wet cleaning and systematic ventilation should be carried out after each hour of work. To maintain the normal parameters of the microclimate in the working area, devices of ventilation, air conditioning and heating systems are used [15].

It is necessary to provide the room with supply and exhaust ventilation in order to reduce the content of harmful substances in the air of the working area below the maximum permissible concentration (MPC), and to organize comfortable work in the cold season, it is necessary to provide the room with a heating system.

For this purpose, the IRT-T reactor has implemented a ventilation scheme consisting of several systems: exhaust and supply, in turn, exhaust is divided into general exchange and special ventilation.

General exchange ventilation extracts air from the reactor rooms and the laboratory annex.

Special ventilation is designed to remove air from places (horizontal channels, a «hot chamber», a radiation pavilion, and others) where radioactive gases and aerosols may appear, purify polluted air and release it through a ventilation pipe.

The performance of the multiplicity of air exchange for the experimental device room is calculated according to the formula [24]:

$$L = n \cdot S \cdot H, \tag{5.3}$$

where n – the multiplicity of air exchange for the room, for industrial premises

n = 3[22];

S – room area, m^2;

H – room height, m.

Calculate the performance using the formula:

$$L = 3 \cdot 24 \cdot 2{,}5 = 180\ м^3/ч. \quad (5.4)$$

The special ventilation system removes air from horizontal channels with a capacity of 500 m^3/h, which is realized with the help of a centrifugal fan CV-5 with an air flow of 6300 m^3/h.

The supply ventilation ensures the supply of heated air up to +18 °C in the cold season in the volume of 60000 m^3/h to the entire reactor building.

Conclusion: for the organization of high-quality air exchange in the room in which the irradiation process is organized, supply and exhaust ventilation with an air exchange of 180 m^3/h is organized on an experimental device. The implemented system of supply and special ventilation is suitable for this, which meets the requirements [22].

5.7 Psychophysiological factors

Neuropsychiatric overload is divided into:

– mental overstrain, including caused by information load;

– overvoltage of analyzers, including caused by information load;

– monotony of work - emotional overload.

Overstrain of the visual analyzers can lead to fatigue and disruption of the contractile function of the eye muscles. Nervous and emotional stress can be caused by responsibility for the work performed, high requirements for the quality of the work performed, the complexity of the work, especially in conditions of time shortage. Nervous and emotional stress can disrupt the functional state of the cardiovascular and central nervous system [15].

To reduce the impact of harmful factors, the limits of the duration of breaks are established. Table 5.4 shows the total rest time for each category of work [25].

Table 5.4 – Total time of breaks depending on the category of work and load

	The level of workload per shift for types of work with a PC			Total time of regulated breaks
Job category	Group A, number of	GroupB, number of	Group C,	at 8-hour shift, min

	characters	characters	hours	
I	до 20 000	до 15 000	до 2	50
II	до 40 000	до 30 000	до 4	70
III	до 60 000	до 40 000	до 6	90

In this case, the load level belongs to group B, work category III. According to the table, it is required to set breaks in the HEC premises, the amount of which for working time will be at least 90 minutes, i.e. breaks of 15 minutes each working hour [25].

5.8 Electrical safety

Electrical safety is achieved by carrying out organizational and technical measures.

Protection against electric shock is achieved by isolating current-carrying parts, blocking equipment and inaccessible location of nodes and mechanisms of devices under voltage. A variety of materials from dielectrics are used for insulation. Blocking provides for disconnecting the supply elements from the devices in case of violation of the integrity of protective devices and fences. The equipment in the HEC room operates from 220 and 380 V and belongs to low-voltage equipment. The site has class I electrical safety up to 1000 V [26].

Depending on the conditions in the room, the risk of electric shock increases or decreases. It is not necessary to work with a computer in conditions of high humidity (relative humidity exceeds 75% for a long time), high temperature (more than 35 °C), the presence of conductive dust, conductive floors and the possibility of simultaneous contact with metal elements connected to the ground and the metal housing of electrical equipment. The computer operator works with electrical appliances: a computer and peripheral devices. There is a risk of electric shock in the following cases:

– when directly touching live parts during computer repair;

– when touching non-current-carrying parts that are energized (in case of a violation of the insulation of the current-carrying parts of the computer);

– when touching the floor, walls that have been energized;

– in case of a short circuit in high-voltage units: the power supply unit and the display scan unit.

Measures to ensure electrical safety of electrical installations:

– disconnecting the voltage from the live parts on which or near which the work will be carried out, and taking measures to ensure that it is impossible to supply voltage to the place of work;

– posting posters indicating the place of work;

– grounding of the housings of all installations through the zero wire;

– coating of metal surfaces of tools with reliable insulation;

– unavailability of current-carrying parts of the equipment (enclosure of electric-reflecting elements, current-carrying parts) [26].

5.9 Fire and explosion safety

Depending on the characteristics of the substances used in the production and their quantity, according to fire and explosion hazard, the premises are divided into categories A, B, C, D, E. Categorization is based according to [27]. Since the room, according to the degree of fire and explosion hazard, belongs to category C, i.e. to rooms with solid combustible substances, it is necessary to provide a number of preventive measures.

Possible causes of fire:

– malfunction of current-carrying parts of installations;

– working with open electrical equipment;

– short circuits in the power supply;

– non-compliance with fire safety regulations;

– the presence of combustible components: documents, doors, tables, cable insulation, etc.

Fire prevention measures are divided into: organizational, technical, operational and regime.

Organizational measures provide for proper operation of equipment, proper maintenance of buildings and territories, fire-fighting instruction of workers and employees, training of production personnel in fire safety rules, publication of instructions, posters, availability of an evacuation plan.

Technical measures include: compliance with fire safety rules, norms in the design of buildings, when installing electrical wires and equipment, heating, ventilation, lighting, proper placement of equipment.

Regime measures include the establishment of rules for the organization of work, and compliance with fire protection measures. To prevent the occurrence of fire from short circuits, overloads, etc., it is necessary to comply with the following fire safety rules:

– exclusion of the formation of a combustible environment (equipment sealing, air control, working and emergency ventilation);

– application of non-combustible or hard-to-burn materials in the construction and decoration of buildings;

– proper operation of the equipment (proper connection of the equipment to the power supply network, control of heating of the equipment);

proper maintenance of buildings and territories (exclusion of ignition source formation – prevention of spontaneous combustion of substances, restriction of fire works);

– training of production personnel in fire safety rules;

– compliance with fire safety rules, norms in the design of buildings, in the installation of electrical wires and equipment, heating, ventilation, lighting;

– correct placement of equipment;

timely preventive inspection, repair and testing of equipment.

In case of an emergency, it is necessary to:

– inform the management (on duty);

– call the emergency service or the Ministry of Emergency Situations – tel. 112;

– take measures to eliminate the accident in accordance with the instructions [27].

5.10 Radiation safety

The main goal of radiation safety is to protect human health from the harmful effects of ionizing radiation by observing the basic principles and standards of radiation safety.

The main document on radiation safety in the organization of work with sources of ionizing radiation is the «Basic sanitary rules for working with radioactive substances and other sources of ionizing radiation».

Sources of ionizing radiation (III) include any substances or objects, including devices that emit or under certain conditions are capable of emitting ionizing radiation. AI is classified by origin as natural and artificial (man-made). The IRT-T reactor and the substances obtained by irradiation are technogenic III.

The IRT-T reactor devices capable of emitting ionizing radiation and irradiated objects were used in the work.

Open sources of ionizing radiation are radionuclide AI, with the use of which there is a possibility of radioactive substances (contained in them) entering the environment. When working with open AI, environmental pollution is possible, and a person is exposed to internal and external radiation.

Under the influence of ionizing radiation in the body, inhibition of the function of hematopoietic organs, violation of normal blood clotting and an increase in the fragility of blood vessels, a decrease in the body's resistance to infectious diseases, etc. can occur. In case of damage to the sealed shell of the radionuclide, protective measures must be taken to prevent radioactive contamination of the air, the surface of the working premises, the skin and clothing of personnel.

There are acceptable levels of doses that a person can receive when working with ionizing radiation sources. The levels are divided according to the category of radiation safety standards.

Personnel (group A) – persons working with man-made sources, ionizing radiation, or who are in the sphere of their influence under working conditions (group B). Population – all persons, including staff outside of work. The limits of permissible doses for Group A personnel and the population are given in Table 5.5 [34].

Table 5.5 – Limits of permissible doses

Normalized values	Dose limits	
	Personnel (Group A)	Population
Effective dose	20 mSv per year on average for any consecutive 5 years, but no more than 50 mSv per year	1 mSv per year on average for any consecutive 5 years, but no more than 5 mSv per year
Equivalent dose per year: In the lens In the skin In the hands and feet	150 mSv 500 mSv 500 mSv	15 mSv 50 mSv 50 mSv

Dose limits and permissible levels for Group B personnel are equal to ¼ of Group A.

In order to ensure conditions under which the radiation exposure will be lower than permissible, taking into account the achieved level in radiation safety, control levels of some radiation factors are additionally established. Table 5.6 shows the control levels set for Group A personnel at the IRT-T reactor [35].

Table 5.6 – Control levels of radiation exposure

Controlled value	Allowed Maximum permissible values (RSS 99/2009)	Control levels
Average annual permissible neutron flux density under external irradiation of the whole body, n/cm^2·s Thermal Intermediate Quick	 990 580-250 14-9,5	 400 250 9
The limit of the effective individual dose, mSv/year	20000 (НРБ 99/2009)	15000
Permissible equivalent dose rate, for permanent residence premises, mSv/h	12,0 (Basic sanitary rules for radiation safety 99/2010)	3,0

When performing work on the IRT-T installation, the dose load mode is determined based on the control levels established by the radiation safety service.

Ensuring radiation safety when working with ionizing radiation sources is achieved by a complex of sanitary, engineering, technical and organizational measures, the list of which depends on the activity of the emitter, the type of radiation, technology and methods of using sources. At the same time, all protective measures are based on the main requirement that the radiation doses of both personnel and persons of other categories do not exceed permissible values.

Protective measures to ensure radiation safety conditions at closed sources are based on knowledge of the laws of ionizing radiation propagation and the nature of its interaction with the substance. The main ones are the following:

– the dose of external radiation is proportional to the intensity of radiation and the time of exposure;

– the intensity of radiation from a point source is proportional to the number of quanta or particles arising in it per unit of time, and inversely proportional to the square of the distance (for extended sources, this dependence is more complex);

– the radiation intensity can be reduced by using screens. From these patterns, the basic principles of radiation safety follow:

– reducing the power of sources to minimum values («protection by quantity»);

– reducing the time spent working with sources («protection by time»);

– increasing the distance from sources to workers («protection by distance»);

– shielding radiation sources with materials that absorb ionizing radiation («screen protection»).

According to the measurements of the gamma radiation dose rate, it can be concluded that there was no excess of the equivalent dose rate in the territory where the work was carried out, which means that these measurements were carried out in a radiation environment safe for humans [36].

5.11 Harmful substances

A person at rest inhales 6-8 liters of air in 1 minute, while working, this volume increases and can reach 100-120 liters/min. Therefore, the presence of even small amounts of harmful substances in the air of the working area can lead to poisoning and diseases. Vapors and gases arising in the production process and during the storage of chemicals can enter the human body through the respiratory organs, gastrointestinal tract, intact skin and at the same time affect its tissues and biochemical systems, causing disruption of normal life processes.

Harmful substances are substances that, upon contact with the human body, can cause occupational diseases or health abnormalities detected by modern methods, both during exposure to the substance and in the long–term life of the present and subsequent generations.

All radiation-hazardous rooms at the reactor are equipped with a special ventilation system. The gas activity of the emitted air is conditioned by the isotope Ar^{41}.

Ar^{41} is formed from Ar^{40} when irradiated with thermal neutrons by the reaction $Ar^{40}(n,g)Ar^{41}$. The atmospheric air contains 0.9 wt. % argon, which consists of 99.5% Ar^{40}, 0.063% – Ar^{38} and 0.337% – Ar^{36}. The emission power depends on the design and technological features of the reactors.

Permissible concentrations of Ar^{41} in the air of working rooms are determined by the recommendations of the ICRP [37]. Table 31 shows the limit values of the concentration of Ar^{41} in the air, which determine the permissible dose rates of external radiation for personnel during a 36-hour working week, depending on the volume of premises, as well as for open areas.

Table 5.7 – Permissible concentrations of Ar^{41} in the air of working rooms

Radionuclide	Half-life, h	Critical organ	Maximum permissible levels of activity in a room with a volume of 50 m^3, Bq/m^3	Minimally significant specific activity, Bq/g	Minimal significant activity, Bq
Ar^{41}	1,827	Skin	$7,6 \cdot 10^5$	$1 \cdot 10^2$	$1 \cdot 10^9$
		Subcutaneous tissue	$1,3 \cdot 10^6$		
		Gonads	$2,4 \cdot 10^6$		

Production premises should be equipped with supply and exhaust ventilation, as well as in places of release and formation of harmful substances - local suction from the production equipment of the technological scheme is placed.

Conclusion: work in the HEC premises is carried out only when special ventilation is turned on, there is no excess dose due to harmful substances, which meets the requirements [37].

5.12 Emergency and emergency situations

All emergency situations are divided into radiation related to radioactive contamination and personnel exposure, and non-radiation.

Radiation emergencies at the reactor include:

– irradiation or radioactive contamination of personnel above the values established by Radiation Safety Standards -99/2009;

– radioactive contamination of industrial premises, equipment, and the environment above the values established by Radiation Safety Standards-99/2009;

– loss of radioactive substances or their presence in an amount that does not correspond to the documents on their receipt;

– the use of RV for other purposes, posing a threat to human health;

– triggering of the «self-sustaining chain reaction» signal.

Non- radiation emergencies include:

– short circuit in power supply systems;

– mechanical breakdown of equipment elements, premises;

– fire;

– natural disaster.

If non-radiation emergencies lead or may lead to radioactive contamination of premises and equipment, irradiation of personnel, then they are considered as radiation emergencies. Table 32 below shows some of the possible accidents and pre-emergency situations, as well as measures to prevent or eliminate them.

Table 5.8 – Emergency and emergency situations and measures to prevent and eliminate their consequences

№	Emergency/ emergency situation	Measures to prevent accidents and emergencies	Measures to eliminate the consequences of emergency and emergency situations
1	Injury due to falling from a height	1. Maintenance of the premises in proper order.	1. Examine or interview the victim; 2. If necessary, call an ambulance (112, 103); 3. Stop the bleeding, if there is any;

	of appropriate height	2. Limitation of the workspace. 3. Timely instruction.	4. If there is a suspicion that the victim has a broken spine, it is necessary to provide the victim with complete rest in the supine position until qualified medical care is provided.
2	Injury due to falling down stairs	1. Installation of handrails on the stairs. 2. Covering the stairs with an anti-slip coating. 3. Timely instruction.	1. Call an ambulance (112, 103); 2. Stop the bleeding, if there is any; 3. If there is a suspicion that the victim's spine is broken (sharp pain in the spine at the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical care is provided.
3	Injury due to electric shock	Injury due to falling down stairs 1. Grounding of all electrical installations. 2. Limitation of the workspace. 3. Ensuring the unavailability of live parts of the equipment. 4. Timely instruction.	1. Quickly release the victim from the action of electric current [9]; 2. Call an ambulance (112, 103); 3. If the victim has lost consciousness, but his breathing has been preserved, he should be comfortably laid down, unbutton the restraining clothes, create an influx of fresh air and ensure complete rest; 4. The victim should be given ammonia to smell, sprinkle his face with water, rub and warm the body; 5. In the absence of breathing, artificial respiration and heart massage should be performed immediately.
4	Fire	1. Timely briefing. 2. Installation of automatic fire extinguishing equipment in the premises. 3. Installation of smoke and fire sensors. 4. Providing escape routes and maintaining them in proper condition. 4. Control of electrical appliances.	1. De-energize the room, stop the air supply; 2. Call firefighters or call emergency services (112, 103, 101); 3. Immediately report the fire to the shift supervisor; 4. If possible, take measures to evacuate people, extinguish a fire and save material assets.
5	Depressurization of the HEC	1. Emergency protection. 2. Installation of water level sensors in the reactor tank. 3. Installation of surveillance cameras in the HEC premises. 4. Periodic monitoring of the	1. Shut down the reactor by pressing the Emergency Protection Button ; 2. Identify the damaged channel; 3. Closing the channel gate manually; 4. All primary circuit pumps are switched off, except for the emergency cooling pump, which runs for 2.5 minutes and turns off with the subsequent opening of the natural circulation valves; 5. The dosimetrist, at the direction of the shift supervisor, monitors the air in the physical hall

		water level in the reactor tank, as well as in the HEC room.	for the possible appearance of radioactive gases and aerosols in it. In case of their occurrence - instructs to leave the physical hall and laboratory premises, with the exception of personnel who will be engaged in the elimination of the consequences of this accident. 6. Protection and equipment are disassembled, the gate is opened, the collimator is removed from the channel. 7. Installation of a shut-off device in the damaged HEC, closing of the valve for the supply of process water to the reactor tank; 8. Further filling of the reactor tank with demineralized water.
6	The fall of a man into the reactor tank	1. To ensure the closed state of the reactor tank. 2. Installation of a barrier around the reactor tank. 3. Instructing the staff. 4. The use of safety belts when working with an open reactor tank.	1. The head of work or a mechanic who is on the upper platform at this time is obliged to take measures to extract the fallen person using a rope, a rod and other means.; 2. If necessary, the head of work involves people in the control room (shift supervisor, control engineer, dosimetrist) to assist the victim.; 3. Closing the channel gate manually; 4. After removing the fallen person, his overalls must be replaced in the airlock. The washing of the body should be carried out in a sanitary inspection. In case of ingestion of water into the body, it is necessary to wash the stomach of the victim; 5. Call an ambulance (103, 112).

5.13 Conclusions on the section

The section identifies dangerous and harmful factors to which an employee may be exposed during research work:

– electromagnetic radiation [15];

– insufficient illumination [19];

– noise [15];

– microclimate [22];

– psychophysical factors [25];

– harmful substances [37].

It is determined that the experimental device relates to:

– to the 1st category of electrical safety [26];

– category B for fire and explosion safety [27].

The room is equipped according to the requirements of electrical safety [26] and fire and explosion safety [27]. If all the rules established by the radiation safety service are observed, retraining does not occur. Based on the above, it follows that the workplace meets the standards for protection from harmful and dangerous factors.

In the final part of the section, measures are considered to prevent the most likely accidents and emergencies at the workplace, as well as measures in case of their occurrence [31].

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Appendix

Appendix 1 – Ambient dose equivalent power values for different dosimetric equipment

Location of the control point	Ambient dose equivalent power neutrons, mSv/h			
	AT1117M*	UNSD-15	Pelican **	Yekaterinburg AT1117M 2022***
3 floor 6 channel	8	12.6	-	0.58
2 floor 6 channel	13.5	29.6	-	17.2
1 floor 8 channel	115	43.6	-	68
1 floor 5.6 channel	1.5	10.2	5.6	1.22

*) – the values obtained by the AT1117M dosimeter-radiometer with the BDKN-03 detector;

**) – values obtained using the standard stationary radiation monitoring system "Pelican" of the IRT-T reactor;

***) – dosimeter-radiometer AT1117M of Yekaterinburg University with a set of spheres for the Bonner method.

Appendix 2 – Data on the dependences of neutron energy on the neutron flux density at the measurement points by the UNSD-15 dosimeter spectrometer

Measuring point 1.6		Measuring point 1.8		Measuring point 2.6		Measuring point 3.6	
Neutron energy, MeV	Neutron flux density, $cm^{-2}s^{-1}$	Neutron energy, MeV	Neutron flux density, $cm^{-2}s^{-1}$	Neutron energy, MeV	Neutron flux density, $cm^{-2}s^{-1}$	Neutron energy, MeV	Neutron flux density, $cm^{-2}s^{-1}$
0.144	4.666752	0.144	22.56826	0.144	10.08331	0.144	1.440432
0.228	7.389024	0.228	35.73307	0.228	15.96524	0.228	2.280684
0.298	8.606538	0.298	43.84206	0.298	18.4605	0.298	2.988642
0.361	9.311995	0.361	48.44945	0.361	19.75031	0.361	3.580037
0.419	9.482389	0.419	51.96103	0.419	20.09398	0.419	4.056339
0.473	9.557438	0.473	53.15716	0.473	19.7539	0.473	4.431064
0.524	9.2617	0.524	54.0039	0.524	19.6159	0.524	4.74429

			6		4		6
0.573	9.108981	0.573	55.0504	0.573	18.82592	0.573	5.044119
0.619	8.852319	0.619	55.37822	0.619	18.4821	0.619	5.28626
0.664	8.580872	0.664	54.95928	0.664	17.57475	0.664	5.54772
0.708	8.323248	0.708	54.53087	0.708	16.97572	0.708	5.727012
0.75	8.001	0.75	53.835	0.75	16.362	0.75	5.874
0.791	7.626822	0.791	53.45024	0.791	15.50439	0.791	6.093864
0.831	7.260447	0.831	52.18514	0.831	14.86244	0.831	6.185964
0.87	7.00698	0.87	50.11809	0.87	14.06529	0.87	6.21267
0.908	6.911696	0.908	48.57891	0.908	13.97049	0.908	6.1063
0.945	6.436395	0.945	47.34639	0.945	13.43979	0.945	6.234165
0.982	5.68087	0.982	47.04467	0.982	11.01313	0.982	6.63832
1.018	5.239646	1.018	46.18971	1.018	9.293322	1.018	7.025218
1.053	4.709016	1.053	43.28778	1.053	9.016839	1.053	7.164612
1.088	4.976512	1.088	40.38656	1.088	8.95424	1.088	7.321152
1.122	5.19486	1.122	36.83975	1.122	8.334216	1.122	7.700286
1.156	5.359216	1.156	33.67775	1.156	7.445796	1.156	7.073564
1.189	5.461077	1.189	28.14244	1.189	6.628675	1.189	5.752382
1.222	5.499	1.222	21.88602	1.222	6.86153	1.222	4.14869
1.254	5.466186	1.254	16.32833	1.254	7.027416	1.254	2.734974
1.286	5.604388	1.286	12.65424	1.286	7.128298	1.286	2.802194
1.317	5.036208	1.317	13.40706	1.317	7.152627	1.317	2.842086
1.348	4.025128	1.348	14.123	1.348	7.102612	1.348	2.855064

1.379	2.869699	1.379	14.79805	1.379	6.974982	1.379	2.836603
1.41	1.89222	1.41	15.4254	1.41	7.08384	1.41	2.78757
1.44	1.93824	1.44	15.98976	1.44	6.28272	1.44	2.70288
1.469	1.972867	1.469	16.48806	1.469	4.924088	1.469	2.582502
1.499	1.995169	1.499	16.9387	1.499	3.398233	1.499	2.429879
1.528	2.004736	1.528	17.50935	1.528	2.113224	1.528	2.241576
1.557	2.002302	1.557	17.51469	1.557	2.125305	1.557	2.020986
1.586	1.984086	1.586	17.18114	1.586	2.122068	1.586	1.766804
1.614	1.951326	1.614	16.73234	1.614	2.103042	1.614	1.480038
1.642	1.90472	1.642	16.42328	1.642	2.06892	1.642	1.16582
1.67	1.84535	1.67	16.86533	1.67	2.01903	1.67	0.82665
1.698	1.772712	1.698	17.26017	1.698	1.9527	1.698	0.463554
1.725	1.685325	1.725	17.59328	1.725	1.8699	1.725	0.084525
1.752	1.587312	1.752	17.87215	1.752	1.771272	1.752	0
1.779	1.478349	1.779	18.09599	1.779	1.658028	1.779	0
1.806	1.359918	1.806	18.26227	1.806	1.531488	1.806	0
1.833	1.235442	1.833	18.37033	1.833	1.391247	1.833	0
1.859	1.102387	1.859	18.40968	1.859	1.239953	1.859	0
1.885	0.967005	1.885	18.39383	1.885	1.080105	1.885	0
1.911	0.831285	1.911	18.32076	1.911	0.911547	1.911	0
1.937	0.695383	1.937	18.19424	1.937	0.737997	1.937	0
1.963	0.565344	1.963	18.01838	1.963	0.561418	1.963	0
1.988	0.44133	1.988	17.7846	1.988	0.38368	1.988	0

	6		5		4		
2.014	0.32626 8	2.014	17.5177 7	2.014	0.20744 2	2.014	0
2.039	0.22632 9	2.039	17.2030 4	2.039	0.03670 2	2.039	0
2.064	0.13622 4	2.064	16.8546 2	2.064	0	2.064	0
2.089	0.06684 8	2.089	16.4759 4	2.089	0	2.089	0
2.113	0.01690 4	2.113	16.0651 4	2.113	0	2.113	0
2.138	0	2.138	15.6437 5	2.138	0	2.138	0
2.163	0	2.163	15.2102 2	2.163	0	2.163	0
2.187	0	2.187	14.7600 6	2.187	0	2.187	0
2.211	0	2.211	14.3073 8	2.211	0	2.211	0
2.235	0	2.235	13.857	2.235	0	2.235	0
2.259	0	2.259	13.4116 8	2.259	0	2.259	0
2.283	0	2.283	13.2025 9	2.283	0	2.283	0
2.306	0	2.306	12.4132	2.306	0	2.306	0
2.33	0	2.33	11.3610 8	2.33	0	2.33	0
2.353	0	2.353	10.3132	2.353	0	2.353	0
2.377	0	2.377	9.53177	2.377	0	2.377	0
2.4	0	2.4	9.6192	2.4	0	2.4	0
2.423	0	2.423	9.692	2.423	0	2.423	0
2.446	0	2.446	9.75220 2	2.446	0.01467 6	2.446	0.03669
2.469	0	2.469	9.79946 1	2.469	0.09629 1	2.469	0.17283
2.491	0	2.491	9.82699 5	2.491	0.18184 3	2.491	0.31635 7
2.514	0	2.514	9.84482 4	2.514	0.27151 2	2.514	0.46509
2.537	0	2.537	9.84863 4	2.537	0.36532 8	2.537	0.61902 8
2.559	0	2.559	9.83167 8	2.559	0.46062	2.559	0.78049 5
2.581	0	2.581	9.80263	2.581	0.56007	2.581	0.94206

			8		7		5
2.604	0	2.604	9.762396	2.604	0.661416	2.604	1.109304
2.626	0	2.626	9.70307	2.626	0.764166	2.626	1.278862
2.648	0	2.648	9.630776	2.648	0.868544	2.648	1.445808
2.67	0	2.67	9.54792	2.67	0.97455	2.67	1.61268
2.692	0	2.692	9.44892	2.692	1.0768	2.692	1.77672
2.713	0.010852	2.713	9.338146	2.713	1.177442	2.713	1.937082
2.735	0.024615	2.735	9.21695	2.735	1.277245	2.735	2.092275
2.757	0.038598	2.757	9.084315	2.757	1.375743	2.757	2.244198
2.778	0.052782	2.778	8.942382	2.778	1.466784	2.778	2.383524
2.8	0.0672	2.8	8.792	2.8	1.554	2.8	2.5172
2.821	0.078988	2.821	8.63226	2.821	1.63618	2.821	2.637635
2.842	0.090944	2.842	8.463476	2.842	1.713726	2.842	2.748214
2.864	0.103104	2.864	8.29128	2.864	1.781408	2.864	2.84968
2.885	0.1154	2.885	8.11262	2.885	1.843515	2.885	2.934045
2.906	0.124958	2.906	7.930474	2.906	1.894712	2.906	3.00771
2.927	0.134642	2.927	7.741915	2.927	1.940601	2.927	3.064569
2.948	0.141504	2.948	7.552776	2.948	1.97516	2.948	3.11014
2.968	0.151368	2.968	7.357672	2.968	2.000432	2.968	3.140144
2.989	0.155428	2.989	7.164633	2.989	2.017575	2.989	3.159373
3.01	0.16254	3.01	6.97116	3.01	2.02272	3.01	3.16351
3.03	0.16665	3.03	6.77811	3.03	2.02101	3.03	3.15423
3.051	0.170856	3.051	6.587109	3.051	2.007558	3.051	3.133377
3.071	0.171976	3.071	6.396893	3.071	1.986937	3.071	3.10171
3.092	0.173152	3.092	6.211828	3.092	1.957236	3.092	3.06108

3.112	0.17116	3.112	6.024832	3.112	1.916992	3.112	3.012416
3.132	0.169128	3.132	5.844312	3.132	1.869804	3.132	2.956608
3.153	0.167109	3.153	5.669094	3.153	1.816128	3.153	2.894454
3.173	0.164996	3.173	5.498809	3.173	1.754669	3.173	2.827143
3.193	0.15965	3.193	5.33231	3.193	1.689097	3.193	2.761945
3.213	0.154224	3.213	5.17293	3.213	1.616139	3.213	2.692494
3.233	0.148718	3.233	5.017616	3.233	1.538908	3.233	2.625196
3.253	0.139879	3.253	4.866488	3.253	1.457344	3.253	2.563364
3.272	0.13088	3.272	4.724768	3.272	1.37424	3.272	2.50308
3.292	0.125096	3.292	4.589048	3.292	1.290464	3.292	2.45254
3.312	0.11592	3.312	4.457952	3.312	1.205568	3.312	2.407824
3.331	0.106592	3.331	4.333631	3.331	1.119216	3.331	2.375003
3.351	0.097179	3.351	4.218909	3.351	1.035459	3.351	2.352402
3.371	0.087646	3.371	4.109249	3.371	0.953993	3.371	2.342845
3.39	0.07797	3.39	4.00698	3.39	0.87123	3.39	2.34588
3.409	0.06818	3.409	3.910123	3.409	0.794297	3.409	2.362437
3.429	0.058293	3.429	3.823335	3.429	0.723519	3.429	2.396871
3.448	0.05172	3.448	3.737632	3.448	0.65512	3.448	2.444632
3.467	0.041604	3.467	3.664619	3.467	0.58939	3.467	2.510108
3.487	0.03487	3.487	3.595097	3.487	0.533511	3.487	2.590841
3.506	0.024542	3.506	3.530542	3.506	0.480322	3.506	2.685596
3.525	0.017625	3.525	3.47565	3.525	0.433575	3.525	2.795325
3.544	0.01063	3.544	3.42350	3.544	0.39692	3.544	2.9238

	2		4		8		
3.563	0.007126	3.563	3.381287	3.563	0.363426	3.563	3.06418
3.582	0	3.582	3.342006	3.582	0.336708	3.582	3.216636
3.601	0	3.601	3.309319	3.601	0.316888	3.601	3.381339
3.619	0	3.619	3.282433	3.619	0.300377	3.619	3.557477
3.638	0	3.638	3.259648	3.638	0.294678	3.638	3.743502
3.657	0	3.657	3.240102	3.657	0.29256	3.657	3.938589
3.676	0	3.676	3.227528	3.676	0.29408	3.676	4.1355
3.694	0	3.694	3.221168	3.694	0.302908	3.694	4.34045
3.713	0	3.713	3.215458	3.713	0.315605	3.713	4.544712
3.731	0	3.731	3.212391	3.731	0.332059	3.731	4.753294
3.75	0	3.75	3.2175	3.75	0.3525	3.75	4.9575
3.768	0	3.768	3.22164	3.768	0.3768	3.768	5.158392
3.787	0	3.787	3.230311	3.787	0.401422	3.787	5.354818
3.805	0	3.805	3.24186	3.805	0.429965	3.805	5.543885
3.823	0.003823	3.823	3.253373	3.823	0.45876	3.823	5.726854
3.842	0.007684	3.842	3.269542	3.842	0.487934	3.842	5.89747
3.86	0.01158	3.86	3.28486	3.86	0.5211	3.86	6.05634
3.878	0.01939	3.878	3.300178	3.878	0.550676	3.878	6.200922
3.896	0.023376	3.896	3.319392	3.896	0.580504	3.896	6.334896
3.914	0.027398	3.914	3.338642	3.914	0.60667	3.914	6.450272
3.932	0.035388	3.932	3.357928	3.932	0.636984	3.932	6.54678
3.95	0.0395	3.95	3.3733	3.95	0.65965	3.95	6.6281
3.968	0.043648	3.968	3.39264	3.968	0.686464	3.968	6.690048

3.986	0.047832	3.986	3.412016	3.986	0.705522	3.986	6.732354
4.004	0.056056	4.004	3.427424	4.004	0.724724	4.004	6.754748
4.022	0.06033	4.022	3.442832	4.022	0.74407	4.022	6.75696
4.04	0.06464	4.04	3.45824	4.04	0.75952	4.04	6.73872
4.058	0.068986	4.058	3.46959	4.058	0.77102	4.058	6.703816
4.075	0.069275	4.075	3.48005	4.075	0.7824	4.075	6.64225
4.093	0.073674	4.093	3.491329	4.093	0.789949	4.093	6.569265
4.111	0.078109	4.111	3.498461	4.111	0.793423	4.111	6.474825
4.128	0.078432	4.128	3.500544	4.128	0.796704	4.128	6.35712
4.146	0.08292	4.146	3.50337	4.146	0.800178	4.146	6.227292
4.163	0.08326	4.163	3.505246	4.163	0.799296	4.163	6.07798
4.181	0.08362	4.181	3.507859	4.181	0.79439	4.181	5.916115
4.198	0.08396	4.198	3.501132	4.198	0.793422	4.198	5.738666
4.216	0.08432	4.216	3.49928	4.216	0.788392	4.216	5.548256
4.233	0.08466	4.233	3.492225	4.233	0.783105	4.233	5.346279
4.251	0.08502	4.251	3.48582	4.251	0.777933	4.251	5.130957
4.268	0.081092	4.268	3.474152	4.268	0.772508	4.268	4.9082
4.285	0.081415	4.285	3.46228	4.285	0.76273	4.285	4.674935
4.302	0.077436	4.302	3.450204	4.302	0.757152	4.302	4.439664
4.32	0.07776	4.32	3.43872	4.32	0.75168	4.32	4.19472
4.337	0.073729	4.337	3.421893	4.337	0.745964	4.337	3.94667
4.354	0.069664	4.354	3.409182	4.354	0.74018	4.354	3.696546
4.371	0.069936	4.371	3.391896	4.371	0.734328	4.371	3.448719

4.388	0.06582	4.388	3.37876	4.388	0.728408	4.388	3.198852
4.405	0.06167	4.405	3.361015	4.405	0.72242	4.405	2.946945
4.422	0.057486	4.422	3.343032	4.422	0.720786	4.422	2.701842
4.439	0.053268	4.439	3.32925	4.439	0.719118	4.439	2.463645
4.456	0.049016	4.456	3.310808	4.456	0.717416	4.456	2.228
4.473	0.04473	4.473	3.296601	4.473	0.71568	4.473	1.999431
4.49	0.0449	4.49	3.28219	4.49	0.71391	4.49	1.77804
4.507	0.040563	4.507	3.272082	4.507	0.716613	4.507	1.563929
4.524	0.036192	4.524	3.25728	4.524	0.714792	4.524	1.361724
4.54	0.03178	4.54	3.2461	4.54	0.71732	4.54	1.17132
4.557	0.027342	4.557	3.23547	4.557	0.720006	4.557	0.988869
4.574	0.02287	4.574	3.229244	4.574	0.718118	4.574	0.82332
4.591	0.018364	4.591	3.218291	4.591	0.720787	4.591	0.665695
4.607	0.018428	4.607	3.215686	4.607	0.723299	4.607	0.525198
4.624	0.013872	4.624	3.209056	4.624	0.721344	4.624	0.397664
4.641	0.009282	4.641	3.206931	4.641	0.723996	4.641	0.283101
4.657	0.009314	4.657	3.204016	4.657	0.721835	4.657	0.181623
4.674	0.004674	4.674	3.206364	4.674	0.719796	4.674	0.098154
4.69	0	4.69	3.20796	4.69	0.71757	4.69	0.02814
4.707	0	4.707	3.210174	4.707	0.715464	4.707	0
4.723	0	4.723	3.21164	4.723	0.713173	4.723	0
4.74	0	4.74	3.21846	4.74	0.711	4.74	0
4.756	0	4.756	3.224568	4.756	0.703888	4.756	0
4.772	0	4.772	3.230644	4.772	0.696712	4.772	0

4.789	0	4.789	3.242153	4.789	0.689616	4.789	0
4.805	0	4.805	3.24818	4.805	0.677505	4.805	0
4.821	0	4.821	3.258996	4.821	0.670119	4.821	0
4.838	0	4.838	3.270488	4.838	0.657968	4.838	0.04838
4.854	0	4.854	3.27645	4.854	0.645582	4.854	0.12135
4.87	0	4.87	3.28725	4.87	0.6331	4.87	0.19967
4.886	0	4.886	3.29805	4.886	0.615636	4.886	0.29316
4.902	0	4.902	3.30885	4.902	0.602946	4.902	0.397062
4.918	0	4.918	3.31965	4.918	0.585242	4.918	0.506554
4.935	0	4.935	3.32619	4.935	0.57246	4.935	0.63168
4.951	0	4.951	3.336974	4.951	0.554512	4.951	0.757503
4.967	0	4.967	3.342791	4.967	0.536436	4.967	0.899027
4.983	0	4.983	3.348576	4.983	0.518232	4.983	1.041447
4.999	0	4.999	3.354329	4.999	0.4999	4.999	1.189762
5.015	0	5.015	3.36005	5.015	0.48144	5.015	1.34402
5.031	0	5.031	3.365739	5.031	0.467883	5.031	1.504269
5.046	0	5.046	3.365682	5.046	0.449094	5.046	1.66518
5.062	0	5.062	3.36623	5.062	0.435332	5.062	1.832444
5.078	0	5.078	3.366714	5.078	0.416396	5.078	2.000732
5.094	0	5.094	3.367134	5.094	0.402426	5.094	2.16495
5.11	0	5.11	3.36749	5.11	0.38836	5.11	2.33527
5.126	0	5.126	3.362656	5.126	0.374198	5.126	2.501488
5.141	0	5.141	3.357073	5.141	0.35987	5.141	2.668179
5.157	0	5.157	3.35205	5.157	0.350676	5.157	2.83635

5.173	0	5.173	3.346931	5.173	0.341418	5.173	2.995167
5.189	0	5.189	3.341716	5.189	0.326907	5.189	3.154912
5.204	0	5.204	3.335764	5.204	0.322648	5.204	3.309744
5.22	0	5.22	3.33036	5.22	0.3132	5.22	3.45564
5.236	0	5.236	3.32486	5.236	0.308924	5.236	3.597132
5.251	0	5.251	3.313381	5.251	0.304558	5.251	3.733461
5.267	0	5.267	3.307676	5.267	0.300219	5.267	3.865978
5.282	0	5.282	3.30125	5.282	0.295792	5.282	3.982628
5.298	0	5.298	3.300654	5.298	0.29139	5.298	4.095354
5.313	0	5.313	3.29406	5.313	0.292215	5.313	4.202583
5.329	0	5.329	3.293322	5.329	0.293095	5.329	4.295174
5.344	0	5.344	3.291904	5.344	0.288576	5.344	4.376736
5.36	0	5.36	3.29104	5.36	0.28944	5.36	4.4488
5.375	0	5.375	3.2895	5.375	0.29025	5.375	4.509625
5.391	0	5.391	3.293901	5.391	0.291114	5.391	4.560786
5.406	0	5.406	3.303066	5.406	0.29733	5.406	4.600506
5.421	0	5.421	3.30681	5.421	0.298155	5.421	4.624113
5.437	0	5.437	3.31657	5.437	0.299035	5.437	4.637761
5.452	0	5.452	3.331172	5.452	0.29986	5.452	4.6342
5.467	0	5.467	3.345804	5.467	0.300685	5.467	4.619615
5.482	0	5.482	3.365948	5.482	0.30151	5.482	4.588434
5.498	0	5.498	3.38127	5.498	0.30239	5.498	4.546846
5.513	0	5.513	3.407034	5.513	0.303215	5.513	4.493095

5.528	0	5.528	3.432888	5.528	0.298512	5.528	4.4224
5.543	0	5.543	3.458832	5.543	0.299322	5.543	4.340169
5.558	0	5.558	3.490424	5.558	0.294574	5.558	4.246312
5.574	0	5.574	3.517194	5.574	0.295422	5.574	4.135908
5.589	0	5.589	3.554604	5.589	0.290628	5.589	4.012902
5.604	0	5.604	3.58656	5.604	0.285804	5.604	3.877968
5.619	0	5.619	3.624255	5.619	0.28095	5.619	3.731016
5.634	0.005634	5.634	3.6621	5.634	0.270432	5.634	3.57759
5.649	0.011298	5.649	3.700095	5.649	0.265503	5.649	3.406347
5.664	0.016992	5.664	3.73824	5.664	0.25488	5.664	3.234144
5.679	0.022716	5.679	3.776535	5.679	0.249876	5.679	3.043944
5.694	0.022776	5.694	3.81498	5.694	0.239148	5.694	2.852694
5.709	0.028545	5.709	3.853575	5.709	0.22836	5.709	2.654685
5.724	0.034344	5.724	3.89232	5.724	0.217512	5.724	2.449872
5.739	0.040173	5.739	3.925476	5.739	0.206604	5.739	2.243949
5.754	0.046032	5.754	3.958752	5.754	0.195636	5.754	2.036916
5.769	0.051921	5.769	3.986379	5.769	0.178839	5.769	1.828773
5.783	0.05783	5.783	4.013402	5.783	0.167707	5.783	1.61924
5.798	0.05798	5.798	4.041206	5.798	0.156546	5.798	1.414712
5.813	0.063943	5.813	4.057474	5.813	0.145325	5.813	1.214917
5.828	0.069936	5.828	4.073772	5.828	0.128216	5.828	1.0199
5.843	0.075959	5.843	4.084257	5.843	0.11686	5.843	0.829706

5.857	0.076141	5.857	4.094043	5.857	0.105426	5.857	0.655984
5.872	0.082208	5.872	4.092784	5.872	0.093952	5.872	0.487376
5.887	0.088305	5.887	4.091465	5.887	0.082418	5.887	0.341446
5.902	0.08853	5.902	4.078282	5.902	0.076726	5.902	0.200668
5.916	0.094656	5.916	4.064292	5.916	0.065076	5.916	0.082824
5.931	0.100827	5.931	4.039011	5.931	0.05931	5.931	0
5.946	0.101082	5.946	4.007604	5.946	0.047568	5.946	0
5.96	0.10728	5.96	3.97532	5.96	0.04172	5.96	0
5.975	0.10755	5.975	3.93155	5.975	0.041825	5.975	0
5.989	0.107802	5.989	3.880872	5.989	0.035934	5.989	0
6.004	0.108072	6.004	3.830552	6.004	0.036024	6.004	0
6.019	0.114361	6.019	3.767894	6.019	0.036114	6.019	0
6.033	0.114627	6.033	3.698229	6.033	0.036198	6.033	0
6.048	0.114912	6.048	3.6288	6.048	0.036288	6.048	0.072576
6.062	0.115178	6.062	3.552332	6.062	0.042434	6.062	0.21217
6.077	0.115463	6.077	3.46389	6.077	0.042539	6.077	0.382851
6.091	0.115729	6.091	3.380505	6.091	0.054819	6.091	0.578645
6.106	0.116014	6.106	3.285028	6.106	0.06106	6.106	0.812098
6.12	0.11016	6.12	3.18852	6.12	0.06732	6.12	1.07712
6.134	0.110412	6.134	3.085402	6.134	0.079742	6.134	1.374016
6.149	0.110682	6.149	2.988414	6.149	0.092235	6.149	1.697124
6.163	0.104771	6.163	2.878121	6.163	0.104771	6.163	2.052279
6.178	0.105026	6.178	2.773922	6.178	0.117382	6.178	2.434132

6.192	0.099072	6.192	2.668752	6.192	0.136224	6.192	2.84832
6.206	0.099296	6.206	2.556872	6.206	0.148944	6.206	3.282974
6.221	0.093315	6.221	2.451074	6.221	0.167967	6.221	3.745042
6.235	0.093525	6.235	2.34436	6.235	0.180815	6.235	4.22733
6.249	0.087486	6.249	2.237142	6.249	0.199968	6.249	4.730493
6.264	0.087696	6.264	2.12976	6.264	0.21924	6.264	5.249232
6.278	0.081614	6.278	2.027794	6.278	0.238564	6.278	5.782038
6.292	0.075504	6.292	1.931644	6.292	0.257972	6.292	6.329752
6.306	0.069366	6.306	1.835046	6.306	0.271158	6.306	6.892458
6.32	0.06952	6.32	1.74432	6.32	0.29072	6.32	7.4576
6.335	0.06335	6.335	1.65977	6.335	0.310415	6.335	8.026445
6.349	0.057141	6.349	1.580901	6.349	0.330148	6.349	8.596546
6.363	0.057267	6.363	1.508031	6.363	0.343602	6.363	9.16272
6.377	0.051016	6.377	1.441202	6.377	0.363489	6.377	9.724925
6.391	0.044737	6.391	1.374065	6.391	0.377069	6.391	10.28312
6.405	0.03843	6.405	1.31943	6.405	0.390705	6.405	10.82445
6.419	0.038514	6.419	1.270962	6.419	0.404397	6.419	11.34879
6.434	0.03217	6.434	1.228894	6.434	0.41821	6.434	11.8643
6.448	0.03224	6.448	1.199328	6.448	0.432016	6.448	12.35437
6.462	0.025848	6.462	1.169622	6.462	0.439416	6.462	12.82061
6.476	0.019428	6.476	1.146252	6.476	0.446844	6.476	13.25637
6.49	0.01947	6.49	1.13575	6.49	0.4543	6.49	13.66794
6.504	0.01300	6.504	1.12519	6.504	0.46178	6.504	14.0486

	8		2		4		4
6.518	0.013036	6.518	1.127614	6.518	0.469296	6.518	14.39174
6.532	0.013064	6.532	1.136568	6.532	0.470304	6.532	14.70353
6.546	0.006546	6.546	1.14555	6.546	0.477858	6.546	14.9707
6.56	0.00656	6.56	1.16768	6.56	0.47888	6.56	15.20608
6.574	0.006574	6.574	1.189894	6.574	0.479902	6.574	15.39631
6.587	0	6.587	1.218595	6.587	0.474264	6.587	15.54532
6.601	0	6.601	1.25419	6.601	0.475272	6.601	15.65097
6.615	0	6.615	1.289925	6.615	0.469665	6.615	15.71724
6.629	0	6.629	1.332429	6.629	0.46403	6.629	15.73725
6.643	0	6.643	1.381744	6.643	0.458367	6.643	15.71734
6.657	0	6.657	1.431255	6.657	0.446019	6.657	15.65061
6.671	0	6.671	1.480962	6.671	0.440286	6.671	15.54343
6.684	0	6.684	1.53732	6.684	0.427776	6.684	15.39325
6.698	0	6.698	1.594124	6.698	0.421974	6.698	15.20446
6.712	0	6.712	1.651152	6.712	0.409432	6.712	14.97447
6.726	0	6.726	1.708404	6.726	0.396834	6.726	14.70304
6.74	0	6.74	1.76588	6.74	0.38418	6.74	14.39664
6.753	0	6.753	1.816557	6.753	0.371415	6.753	14.05975
6.767	0	6.767	1.874459	6.767	0.358651	6.767	13.68287
6.781	0	6.781	1.932585	6.781	0.345831	6.781	13.28398
6.794	0	6.794	1.983848	6.794	0.326112	6.794	12.84745
6.808	0	6.808	2.03559	6.808	0.31316	6.808	12.3973

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6.822	0	6.822	2.087532	6.822	0.300168	6.822	11.91803
6.835	0	6.835	2.13252	6.835	0.28707	6.835	11.41445
6.849	0	6.849	2.177982	6.849	0.267111	6.849	10.90361
6.863	0	6.863	2.216749	6.863	0.253931	6.863	10.36999
6.876	0	6.876	2.255328	6.876	0.24066	6.876	9.83268
6.89	0	6.89	2.29437	6.89	0.22737	6.89	9.28083
6.904	0	6.904	2.326648	6.904	0.214024	6.904	8.726656
6.917	0	6.917	2.358697	6.917	0.200593	6.917	8.168977
6.931	0	6.931	2.384264	6.931	0.187137	6.931	7.610238
6.944	0	6.944	2.409568	6.944	0.180544	6.944	7.04816
6.958	0	6.958	2.428342	6.958	0.166992	6.958	6.498772
6.971	0	6.971	2.446821	6.971	0.160333	6.971	5.960205
6.985	0	6.985	2.45872	6.985	0.146685	6.985	5.427345
6.998	0	6.998	2.470294	6.998	0.13996	6.998	4.905598
7.012	0	7.012	2.475236	7.012	0.133228	7.012	4.403536
7.025	0	7.025	2.479825	7.025	0.12645	7.025	3.912925
7.039	0	7.039	2.484767	7.039	0.126702	7.039	3.44911
7.052	0	7.052	2.482304	7.052	0.119884	7.052	2.9971
7.066	0	7.066	2.487232	7.066	0.120122	7.066	2.572024
7.079	0	7.079	2.47765	7.079	0.120343	7.079	2.166174
7.092	0	7.092	2.475108	7.092	0.120564	7.092	1.787184
7.106	0	7.106	2.465782	7.106	0.120802	7.106	1.428306

7.119	0	7.119	2.463174	7.119	0.121023	7.119	1.096326
7.133	0	7.133	2.453752	7.133	0.128394	7.133	0.798896
7.146	0	7.146	2.443932	7.146	0.128628	7.146	0.521658
7.159	0	7.159	2.43406	7.159	0.136021	7.159	0.272042
7.173	0	7.173	2.424474	7.173	0.14346	7.173	0.050211
7.186	0	7.186	2.40731	7.186	0.150906	7.186	0
7.199	0	7.199	2.397267	7.199	0.158378	7.199	0
7.212	0	7.212	2.387172	7.212	0.165876	7.212	0
7.226	0	7.226	2.377354	7.226	0.173424	7.226	0
7.239	0	7.239	2.367153	7.239	0.188214	7.239	0
7.252	0	7.252	2.3569	7.252	0.195804	7.252	0
7.266	0	7.266	2.346918	7.266	0.210714	7.266	0
7.279	0	7.279	2.336559	7.279	0.21837	7.279	0
7.292	0	7.292	2.33344	7.292	0.233344	7.292	0
7.305	0	7.305	2.32299	7.305	0.241065	7.305	0
7.318	0	7.318	2.319806	7.318	0.25613	7.318	0
7.332	0	7.332	2.316912	7.332	0.263952	7.332	0
7.345	0	7.345	2.313675	7.345	0.27911	7.345	0
7.358	0	7.358	2.310412	7.358	0.286962	7.358	0
7.371	0	7.371	2.307123	7.371	0.29484	7.371	0
7.384	0	7.384	2.311192	7.384	0.310128	7.384	0
7.397	0	7.397	2.307864	7.397	0.318071	7.397	0

7.41	0	7.41	2.31192	7.41	0.32604	7.41	0.02964
7.423	0	7.423	2.315976	7.423	0.334035	7.423	0.178152
7.437	0	7.437	2.320344	7.437	0.342102	7.437	0.334665
7.45	0	7.45	2.3244	7.45	0.3427	7.45	0.49915
7.463	0	7.463	2.328456	7.463	0.350761	7.463	0.664207
7.476	0	7.476	2.332512	7.476	0.351372	7.476	0.837312
7.489	0	7.489	2.344057	7.489	0.351983	7.489	1.011015
7.502	0	7.502	2.348126	7.502	0.352594	7.502	1.185316
7.515	0	7.515	2.35971	7.515	0.353205	7.515	1.360215
7.528	0	7.528	2.37132	7.528	0.346288	7.528	1.528184
7.541	0	7.541	2.375415	7.541	0.346886	7.541	1.696725
7.554	0	7.554	2.387064	7.554	0.33993	7.554	1.858284
7.567	0	7.567	2.398739	7.567	0.332948	7.567	2.012822
7.58	0	7.58	2.40286	7.58	0.32594	7.58	2.16788
7.593	0	7.593	2.414574	7.593	0.318906	7.593	2.308272
7.606	0	7.606	2.426314	7.606	0.30424	7.606	2.449132
7.619	0	7.619	2.430461	7.619	0.297141	7.619	2.575222
7.632	0	7.632	2.44224	7.632	0.282384	7.632	2.694096
7.644	0	7.644	2.453724	7.644	0.26754	7.644	2.797704
7.657	0	7.657	2.457897	7.657	0.252681	7.657	2.894346
7.67	0	7.67	2.46207	7.67	0.23777	7.67	2.98363
7.683	0	7.683	2.473926	7.683	0.222807	7.683	3.050151
7.696	0	7.696	2.478112	7.696	0.207792	7.696	3.11688
7.709	0	7.709	2.482298	7.709	0.192725	7.709	3.16069

7.722	0	7.722	2.478762	7.722	0.169884	7.722	3.196908
7.734	0	7.734	2.482614	7.734	0.15468	7.734	3.217344
7.747	0	7.747	2.486787	7.747	0.139446	7.747	3.222752
7.76	0.00776	7.76	2.4832	7.76	0.1164	7.76	3.2204
7.773	0.015546	7.773	2.479587	7.773	0.101049	7.773	3.202476
7.786	0.023358	7.786	2.475948	7.786	0.085646	7.786	3.168902
7.798	0.031192	7.798	2.464168	7.798	0.062384	7.798	3.1192
7.811	0.039055	7.811	2.460465	7.811	0.046866	7.811	3.061912
7.824	0.03912	7.824	2.448912	7.824	0.031296	7.824	2.988768
7.837	0.047022	7.837	2.437307	7.837	0.015674	7.837	2.907527
7.85	0.05495	7.85	2.42565	7.85	0	7.85	2.8103
7.862	0.055034	7.862	2.405772	7.862	0	7.862	2.704528
7.875	0.055125	7.875	2.386125	7.875	0	7.875	2.590875
7.888	0.055216	7.888	2.3664	7.888	0	7.888	2.461056
7.9	0.0632	7.9	2.3463	7.9	0	7.9	2.3305
7.913	0.055391	7.913	2.318509	7.913	0	7.913	2.183988
7.926	0.055482	7.926	2.290614	7.926	0	7.926	2.036982
7.938	0.055566	7.938	2.26233	7.938	0	7.938	1.873368
7.951	0.055657	7.951	2.234231	7.951	0	7.951	1.709465
7.964	0.047784	7.964	2.198064	7.964	0	7.964	1.545016
7.976	0.03988	7.976	2.161496	7.976	0	7.976	1.371872
7.989	0.039945	7.989	2.125074	7.989	0	7.989	1.19835
8.002	0.032008	8.002	2.088522	8.002	0	8.002	1.024256
8.014	0.02404	8.014	2.04357	8.014	0	8.014	0.84948

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8.027	0.016054	8.027	1.998723	8.027	0	8.027	0.674268
8.039	0.008039	8.039	1.945438	8.039	0	8.039	0.506457
8.052	0	8.052	1.900272	8.052	0	8.052	0.330132
8.064	0	8.064	1.846656	8.064	0	8.064	0.169344
8.077	0	8.077	1.785017	8.077	0	8.077	0.008077
8.09	0	8.09	1.73126	8.09	0	8.09	0
8.102	0	8.102	1.669012	8.102	0	8.102	0
8.115	0	8.115	1.60677	8.115	0	8.115	0
8.127	0	8.127	1.536003	8.127	0	8.127	0
8.14	0	8.14	1.4652	8.14	0	8.14	0
8.152	0	8.152	1.393992	8.152	0	8.152	0
8.165	0	8.165	1.314565	8.165	0	8.165	0
8.177	0	8.177	1.234727	8.177	0	8.177	0
8.19	0	8.19	1.15479	8.19	0	8.19	0
8.202	0	8.202	1.06626	8.202	0	8.202	0
8.214	0	8.214	0.977466	8.214	0	8.214	0
8.227	0	8.227	0.880289	8.227	0	8.227	0
8.239	0	8.239	0.782705	8.239	0	8.239	0
8.252	0	8.252	0.684916	8.252	0	8.252	0
8.264	0	8.264	0.57848	8.264	0	8.264	0
8.277	0	8.277	0.463512	8.277	0	8.277	0
8.289	0	8.289	0.356427	8.289	0	8.289	0
8.301	0	8.301	0.240729	8.301	0	8.301	0
8.314	0	8.314	0.116396	8.314	0	8.314	0
8.326	0	8.326	0	8.326	0	8.326	0

8.338	0	8.338	0	8.338	0.016676	8.338	0
8.351	0	8.351	0	8.351	0.033404	8.351	0
8.363	0	8.363	0	8.363	0.041815	8.363	0
8.375	0	8.375	0	8.375	0.058625	8.375	0
8.388	0	8.388	0	8.388	0.075492	8.388	0
8.4	0.0168	8.4	0	8.4	0.0924	8.4	0
8.412	0.025236	8.412	0	8.412	0.109356	8.412	0
8.425	0.042125	8.425	0	8.425	0.1348	8.425	0.075825
8.437	0.059059	8.437	0	8.437	0.151866	8.437	0.210925
8.449	0.076041	8.449	0	8.449	0.16898	8.449	0.354858
8.461	0.08461	8.461	0	8.461	0.194603	8.461	0.490738
8.474	0.101688	8.474	0	8.474	0.21185	8.474	0.63555
8.486	0.118804	8.486	0	8.486	0.237608	8.486	0.76374
8.498	0.135968	8.498	0	8.498	0.25494	8.498	0.900788
8.51	0.14467	8.51	0	8.51	0.28083	8.51	1.02971
8.523	0.161937	8.523	0	8.523	0.306828	8.523	1.150605
8.535	0.179235	8.535	0	8.535	0.332865	8.535	1.26318
8.547	0.188034	8.547	0	8.547	0.350427	8.547	1.36752
8.559	0.205416	8.559	0	8.559	0.376596	8.559	1.463589
8.571	0.214275	8.571	0	8.571	0.402837	8.571	1.551351
8.584	0.223184	8.584	0	8.584	0.420616	8.584	1.63096
8.596	0.240688	8.596	0	8.596	0.446992	8.596	1.702008
8.608	0.249632	8.608	0	8.608	0.464832	8.608	1.756032

8.62	0.2586	8.62	0	8.62	0.49134	8.62	1.80158
8.632	0.25896	8.632	0	8.632	0.509288	8.632	1.838616
8.644	0.267964	8.644	0	8.644	0.527284	8.644	1.867104
8.656	0.268336	8.656	0	8.656	0.545328	8.656	1.878352
8.669	0.277408	8.669	0	8.669	0.563485	8.669	1.881173
8.681	0.277792	8.681	0	8.681	0.581627	8.681	1.875096
8.693	0.278176	8.693	0	8.693	0.591124	8.693	1.860302
8.705	0.27856	8.705	0	8.705	0.600645	8.705	1.836755
8.717	0.278944	8.717	0	8.717	0.61019	8.717	1.813136
8.729	0.270599	8.729	0	8.729	0.619759	8.729	1.771987
8.741	0.270971	8.741	0	8.741	0.629352	8.741	1.730718
8.753	0.26259	8.753	0	8.753	0.630216	8.753	1.689329
8.765	0.254185	8.765	0	8.765	0.63108	8.765	1.639055
8.777	0.254533	8.777	0	8.777	0.631944	8.777	1.588637
8.789	0.246092	8.789	0	8.789	0.624019	8.789	1.538075
8.801	0.237627	8.801	0	8.801	0.624871	8.801	1.487369
8.813	0.220325	8.813	0	8.813	0.61691	8.813	1.436519
8.825	0.2118	8.825	0	8.825	0.6001	8.825	1.39435
8.837	0.203251	8.837	0	8.837	0.592079	8.837	1.352061
8.849	0.194678	8.849	0	8.849	0.575185	8.849	1.318501
8.861	0.17722	8.861	0.115193	8.861	0.558243	8.861	1.293706
8.873	0.168587	8.873	0.417031	8.873	0.541253	8.873	1.277712
8.885	0.15993	8.885	0.719685	8.885	0.51533	8.885	1.27944

8.897	0.142352	8.897	1.032052	8.897	0.498232	8.897	1.281168
8.909	0.133635	8.909	1.345259	8.909	0.472177	8.909	1.300714
8.921	0.115973	8.921	1.668227	8.921	0.44605	8.921	1.329229
8.933	0.107196	8.933	1.992059	8.933	0.419851	8.933	1.366749
8.945	0.098395	8.945	2.30781	8.945	0.39358	8.945	1.422255
8.957	0.08957	8.957	2.624401	8.957	0.367237	8.957	1.495819
8.969	0.071752	8.969	2.941832	8.969	0.340822	8.969	1.578544
8.981	0.062867	8.981	3.242141	8.981	0.314335	8.981	1.679447
8.993	0.053958	8.993	3.543242	8.993	0.278783	8.993	1.7986
9.004	0.04502	9.004	3.8267	9.004	0.252112	9.004	1.926856
9.016	0.036064	9.016	4.10228	9.016	0.2254	9.016	2.064664
9.028	0.027084	9.028	4.360524	9.028	0.198616	9.028	2.220888
9.04	0.02712	9.04	4.6104	9.04	0.17176	9.04	2.3956
9.052	0.018104	9.052	4.833768	9.052	0.144832	9.052	2.570768
9.064	0.009064	9.064	5.039584	9.064	0.117832	9.064	2.76452
9.076	0.009076	9.076	5.227776	9.076	0.099836	9.076	2.967852
9.087	0.009087	9.087	5.397678	9.087	0.081783	9.087	3.171363
9.099	0	9.099	5.532192	9.099	0.063693	9.099	3.384828
9.111	0	9.111	5.657931	9.111	0.045555	9.111	3.607956
9.123	0	9.123	5.74749	9.123	0.027369	9.123	3.83166
9.135	0	9.135	5.818995	9.135	0.01827	9.135	4.05594
9.146	0	9.146	5.862586	9.146	0.009146	9.146	4.289474
9.158	0	9.158	5.88859	9.158	0	9.158	4.51489

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9.17	0	9.17	5.87797	9.17	0	9.17	4.73172
9.182	0	9.182	5.848934	9.182	0	9.182	4.949098
9.194	0	9.194	5.79222	9.194	0	9.194	5.157834
9.205	0	9.205	5.716305	9.205	0	9.205	5.35731
9.217	0	9.217	5.613153	9.217	0.009217	9.217	5.548634
9.229	0	9.229	5.491255	9.229	0.018458	9.229	5.731209
9.241	0	9.241	5.341298	9.241	0.027723	9.241	5.895758
9.252	0	9.252	5.171868	9.252	0.04626	9.252	6.050808
9.264	0	9.264	4.993296	9.264	0.064848	9.264	6.179088
9.276	0	9.276	4.795692	9.276	0.083484	9.276	6.298404
9.287	0	9.287	4.578491	9.287	0.102157	9.287	6.398743
9.299	0	9.299	4.342633	9.299	0.120887	9.299	6.472104
9.311	0	9.311	4.106151	9.311	0.148976	9.311	6.527011
9.322	0	9.322	3.859308	9.322	0.177118	9.322	6.562688
9.334	0	9.334	3.59359	9.334	0.205348	9.334	6.58047
9.346	0	9.346	3.336522	9.346	0.23365	9.346	6.570238
9.357	0	9.357	3.069096	9.357	0.261996	9.357	6.531186
9.369	0	9.369	2.801331	9.369	0.290439	9.369	6.473979
9.381	0	9.381	2.53287	9.381	0.318954	9.381	6.397842
9.392	0	9.392	2.272864	9.392	0.356896	9.392	6.29264
9.404	0	9.404	2.012456	9.404	0.385564	9.404	6.169024
9.416	0	9.416	1.760792	9.416	0.414304	9.416	6.02624

9.427	0	9.427	1.517747	9.427	0.443069	9.427	5.863594
9.439	0	9.439	1.283704	9.439	0.47195	9.439	5.672839
9.45	0	9.45	1.06785	9.45	0.50085	9.45	5.47155
9.462	0	9.462	0.861042	9.462	0.529872	9.462	5.241948
9.474	0	9.474	0.66318	9.474	0.558966	9.474	5.002272
9.485	0	9.485	0.49322	9.485	0.578585	9.485	4.751985
9.497	0	9.497	0.332395	9.497	0.598311	9.497	4.482584
9.508	0	9.508	0.19016	9.508	0.61802	9.508	4.193028
9.52	0	9.52	0.06664	9.52	0.63784	9.52	3.9032
9.531	0	9.531	0	9.531	0.657639	9.531	3.593187
9.543	0	9.543	0	9.543	0.66801	9.543	3.282792
9.554	0	9.554	0	9.554	0.678334	9.554	2.96174
9.566	0	9.566	0	9.566	0.688752	9.566	2.640216
9.578	0	9.578	0	9.578	0.699194	9.578	2.308298
9.589	0	9.589	0	9.589	0.699997	9.589	1.984923
9.601	0	9.601	0	9.601	0.700873	9.601	1.651372
9.612	0	9.612	0	9.612	0.701676	9.612	1.326456
9.624	0	9.624	0	9.624	0.692928	9.624	1.000896
9.635	0	9.635	0	9.635	0.69372	9.635	0.67445
9.646	0	9.646	0	9.646	0.684866	9.646	0.356902
9.658	0	9.658	0	9.658	0.666402	9.658	0.04829
9.669	0	9.669	0.067683	9.669	0.657492	9.669	0
9.681	0	9.681	0.164577	9.681	0.638946	9.681	0
9.692	0	9.692	0.28106	9.692	0.62028	9.692	0

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9.704	0	9.704	0.397864	9.704	0.601648	9.704	0
9.715	0	9.715	0.52461	9.715	0.5829	9.715	0
9.727	0	9.727	0.651709	9.727	0.564166	9.727	0
9.738	0	9.738	0.77904	9.738	0.545328	9.738	0
9.75	0	9.75	0.9165	9.75	0.51675	9.75	0
9.761	0	9.761	1.044427	9.761	0.48805	9.761	0
9.772	0	9.772	1.17264	9.772	0.469056	9.772	0
9.784	0	9.784	1.301272	9.784	0.44028	9.784	0
9.795	0	9.795	1.43007	9.795	0.41139	9.795	0
9.806	0	9.806	1.549348	9.806	0.382434	9.806	0
9.818	0	9.818	1.659242	9.818	0.353448	9.818	0
9.829	0	9.829	1.76922	9.829	0.324357	9.829	0
9.841	0	9.841	1.859949	9.841	0.305071	9.841	0
9.852	0	9.852	1.950696	9.852	0.275856	9.852	0
9.863	0	9.863	2.021915	9.863	0.246575	9.863	0
9.875	0	9.875	2.0935	9.875	0.21725	9.875	0
9.886	0	9.886	2.155148	9.886	0.187834	9.886	0
9.897	0	9.897	2.197134	9.897	0.168249	9.897	0
9.909	0	9.909	2.229525	9.909	0.138726	9.909	0
9.92	0	9.92	2.26176	9.92	0.11904	9.92	0
9.931	0	9.931	2.274199	9.931	0.089379	9.931	0
9.943	0	9.943	2.276947	9.943	0.069601	9.943	0
9.954	0	9.954	2.259558	9.954	0.04977	9.954	0
9.965	0	9.965	2.242125	9.965	0.029895	9.965	0

9.976	0	9.976	2.214672	9.976	0.009976	9.976	0
9.988	0	9.988	2.177384	9.988	0	9.988	0
9.999	0	9.999	2.139786	9.999	0	9.999	0
10.01	0	10.01	2.08208	10.01	0	10.01	0
10.022	0	10.022	2.024444	10.022	0	10.022	0
10.033	0	10.033	1.956435	10.033	0	10.033	0
10.044	0	10.044	1.888272	10.044	0	10.044	0
10.055	0	10.055	1.8099	10.055	0	10.055	0
10.067	0	10.067	1.731524	10.067	0	10.067	0
10.078	0	10.078	1.652792	10.078	0	10.078	0
10.089	0	10.089	1.563795	10.089	0	10.089	0
10.1	0	10.1	1.4847	10.1	0	10.1	0
10.111	0	10.111	1.395318	10.111	0	10.111	0
10.123	0	10.123	1.31599	10.123	0	10.123	0
10.134	0	10.134	1.236348	10.134	0	10.134	0
10.145	0	10.145	1.15653	10.145	0	10.145	0
10.156	0	10.156	1.086692	10.156	0	10.156	0
10.167	0	10.167	1.0167	10.167	0	10.167	0
10.179	0	10.179	0.946647	10.179	0	10.179	0
10.19	0	10.19	0.88653	10.19	0	10.19	0
10.201	0	10.201	0.836482	10.201	0	10.201	0
10.212	0	10.212	0.786324	10.212	0	10.212	0.05106
10.223	0	10.223	0.736056	10.223	0	10.223	0.255575
10.234	0	10.234	0.706146	10.234	0	10.234	0.450296
10.245	0	10.245	0.67617	10.245	0	10.245	0.65568
10.257	0	10.257	0.656448	10.257	0	10.257	0.851331

10.268	0	10.268	0.636616	10.268	0	10.268	1.037068
10.279	0	10.279	0.627019	10.279	0	10.279	1.223201
10.29	0	10.29	0.62769	10.29	0	10.29	1.40973
10.301	0	10.301	0.628361	10.301	0	10.301	1.596655
10.312	0	10.312	0.639344	10.312	0	10.312	1.763352
10.323	0	10.323	0.650349	10.323	0	10.323	1.940724
10.334	0	10.334	0.67171	10.334	0	10.334	2.097802
10.345	0	10.345	0.70346	10.345	0	10.345	2.25521
10.356	0	10.356	0.72492	10.356	0	10.356	2.402592
10.368	0	10.368	0.767232	10.368	0	10.368	2.550528
10.379	0	10.379	0.799183	10.379	0	10.379	2.688161
10.39	0	10.39	0.84159	10.39	0	10.39	2.81569
10.401	0	10.401	0.884085	10.401	0	10.401	2.943483
10.412	0	10.412	0.926668	10.412	0	10.412	3.061128
10.423	0	10.423	0.979762	10.423	0	10.423	3.168592
10.434	0	10.434	1.022532	10.434	0	10.434	3.265842
10.445	0	10.445	1.075835	10.445	0	10.445	3.36329
10.456	0	10.456	1.118792	10.456	0	10.456	3.45048
10.467	0	10.467	1.161837	10.467	0	10.467	3.537846
10.478	0	10.478	1.20497	10.478	0	10.478	3.604432
10.489	0	10.489	1.248191	10.489	0	10.489	3.681639
10.5	0	10.5	1.2915	10.5	0	10.5	3.738
10.511	0	10.511	1.324386	10.511	0	10.511	3.794471
10.522	0	10.522	1.357338	10.522	0	10.522	3.851052

10.533	0	10.533	1.390356	10.533	0	10.533	3.89721
10.544	0	10.544	1.42344	10.544	0	10.544	3.943456
10.555	0	10.555	1.446035	10.555	0	10.555	3.979235
10.566	0	10.566	1.458108	10.566	0	10.566	4.025646
10.577	0	10.577	1.470203	10.577	0.042308	10.577	4.050991
10.588	0	10.588	1.48232	10.588	0.084704	10.588	4.086968
10.599	0	10.599	1.494459	10.599	0.127188	10.599	4.112412
10.61	0	10.61	1.4854	10.61	0.18037	10.61	4.12729
10.621	0	10.621	1.48694	10.621	0.223041	10.621	4.152811
10.631	0	10.631	1.477709	10.631	0.276406	10.631	4.167352
10.642	0	10.642	1.457954	10.642	0.31926	10.642	4.182306
10.653	0	10.653	1.438155	10.653	0.362202	10.653	4.197282
10.664	0	10.664	1.418312	10.664	0.394568	10.664	4.201616
10.675	0	10.675	1.38775	10.675	0.437675	10.675	4.216625
10.686	0	10.686	1.357122	10.686	0.48087	10.686	4.22097
10.697	0	10.697	1.326428	10.697	0.513456	10.697	4.214618
10.708	0	10.708	1.28496	10.708	0.546108	10.708	4.218952
10.719	0	10.719	1.243404	10.719	0.568107	10.719	4.212567
10.73	0	10.73	1.20176	10.73	0.60088	10.73	4.20616
10.74	0	10.74	1.14918	10.74	0.62292	10.74	4.1886
10.751	0	10.751	1.096602	10.751	0.64506	10.751	4.171388
10.762	0	10.762	1.043914	10.762	0.656482	10.762	4.14337
10.773	0	10.773	0.991116	10.773	0.678699	10.773	4.115286
10.784	0	10.784	0.93820	10.784	0.69017	10.784	4.07635

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10.795	0	10.795	0.874395	10.795	0.69088	10.795	4.03733
10.806	0	10.806	0.821256	10.806	0.70239	10.806	3.976608
10.816	0	10.816	0.75712	10.816	0.70304	10.816	3.926208
10.827	0	10.827	0.692928	10.827	0.703755	10.827	3.854412
10.838	0	10.838	0.628604	10.838	0.693632	10.838	3.782462
10.849	0	10.849	0.574997	10.849	0.683487	10.849	3.68866
10.86	0	10.86	0.51042	10.86	0.67332	10.86	3.59466
10.87	0	10.87	0.44567	10.87	0.66307	10.87	3.48927
10.881	0	10.881	0.380835	10.881	0.65286	10.881	3.37311
10.892	0	10.892	0.32676	10.892	0.631736	10.892	3.256708
10.903	0	10.903	0.261672	10.903	0.610568	10.903	3.118258
10.914	0	10.914	0.196452	10.914	0.589356	10.914	2.968608
10.924	0	10.924	0.142012	10.924	0.568048	10.924	2.807468
10.935	0	10.935	0.08748	10.935	0.54675	10.935	2.635335
10.946	0	10.946	0.021892	10.946	0.514462	10.946	2.46285
10.957	0	10.957	0	10.957	0.493065	10.957	2.268099
10.968	0	10.968	0	10.968	0.460656	10.968	2.072952
10.978	0	10.978	0	10.978	0.428142	10.978	1.855282
10.989	0	10.989	0	10.989	0.406593	10.989	1.637361
11	0	11	0	11	0.374	11	1.408
11.011	0	11.011	0	11.011	0.341341	11.011	1.178177
11.021	0	11.021	0	11.021	0.308588	11.021	0.936785
11.032	0	11.032	0	11.032	0.286832	11.032	0.683984

11.043	0	11.043	0	11.043	0.253989	11.043	0.430677
11.053	0	11.053	0	11.053	0.232113	11.053	0.176848
11.064	0	11.064	0	11.064	0.199152	11.064	0
11.075	0	11.075	0	11.075	0.1772	11.075	0
11.086	0	11.086	0	11.086	0.155204	11.086	0
11.096	0	11.096	0	11.096	0.133152	11.096	0
11.107	0	11.107	0	11.107	0.11107	11.107	0
11.118	0	11.118	0	11.118	0.088944	11.118	0
11.128	0	11.128	0	11.128	0.066768	11.128	0
11.139	0	11.139	0	11.139	0.055695	11.139	0
11.15	0	11.15	0	11.15	0.0446	11.15	0
11.16	0	11.16	0	11.16	0.03348	11.16	0
11.171	0	11.171	0	11.171	0.022342	11.171	0
11.182	0	11.182	0	11.182	0.011182	11.182	0
11.192	0	11.192	0	11.192	0.011192	11.192	0
11.203	0	11.203	0	11.203	0	11.203	0
11.214	0	11.214	0	11.214	0	11.214	0
11.224	0	11.224	0	11.224	0	11.224	0
11.235	0	11.235	0	11.235	0	11.235	0
11.245	0	11.245	0	11.245	0	11.245	0
11.256	0	11.256	0	11.256	0	11.256	0
11.267	0	11.267	0	11.267	0	11.267	0
11.277	0	11.277	0	11.277	0	11.277	0
11.288	0	11.288	0	11.288	0	11.288	0
11.298	0	11.298	0	11.298	0	11.298	0
11.309	0	11.309	0	11.309	0	11.309	0
11.32	0	11.32	0	11.32	0	11.32	0
11.33	0	11.33	0	11.33	0	11.33	0
11.341	0	11.341	0	11.341	0	11.341	0
11.351	0	11.351	0.079457	11.351	0	11.351	0
11.362	0	11.362	0.17043	11.362	0	11.362	0
11.373	0	11.373	0.27295	11.373	0	11.373	0

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11.383	0	11.383	0.387022	11.383	0	11.383	0
11.394	0	11.394	0.501336	11.394	0	11.394	0
11.404	0	11.404	0.62722	11.404	0	11.404	0
11.415	0	11.415	0.75339	11.415	0	11.415	0
11.425	0	11.425	0.879725	11.425	0	11.425	0
11.436	0	11.436	1.017804	11.436	0	11.436	0
11.446	0	11.446	1.156046	11.446	0	11.446	0
11.457	0	11.457	1.306098	11.457	0	11.457	0
11.467	0	11.467	1.456309	11.467	0	11.467	0
11.478	0	11.478	1.60692	11.478	0	11.478	0
11.488	0	11.488	1.757664	11.488	0	11.488	0
11.499	0	11.499	1.908834	11.499	0	11.499	0
11.509	0	11.509	2.07162	11.509	0	11.509	0
11.52	0	11.52	2.22336	11.52	0	11.52	0
11.53	0	11.53	2.38671	11.53	0	11.53	0
11.541	0	11.541	2.53902	11.541	0	11.541	0
11.551	0	11.551	2.691383	11.551	0	11.551	0
11.562	0	11.562	2.844252	11.562	0	11.562	0
11.572	0	11.572	2.985576	11.572	0	11.572	0
11.583	0	11.583	3.138993	11.583	0	11.583	0
11.593	0	11.593	3.280819	11.593	0	11.593	0
11.604	0	11.604	3.411576	11.604	0	11.604	0
11.614	0	11.614	3.54227	11.614	0	11.614	0
11.625	0	11.625	3.661875	11.625	0	11.625	0
11.635	0	11.635	3.76974	11.635	0	11.635	0
11.646	0	11.646	3.878118	11.646	0	11.646	0

11.656	0	11.656	3.974696	11.656	0	11.656	0
11.666	0	11.666	4.071434	11.666	0	11.666	0
11.677	0	11.677	4.145335	11.677	0	11.677	0
11.687	0	11.687	4.20732	11.687	0	11.687	0
11.698	0	11.698	4.26977	11.698	0	11.698	0
11.708	0	11.708	4.320252	11.708	0	11.708	0
11.718	0	11.718	4.347378	11.718	0	11.718	0
11.729	0	11.729	4.374917	11.729	0	11.729	0
11.739	0	11.739	4.378647	11.739	0	11.739	0
11.75	0	11.75	4.38275	11.75	0	11.75	0
11.76	0	11.76	4.36296	11.76	0	11.76	0
11.77	0	11.77	4.34313	11.77	0	11.77	0
11.781	0	11.781	4.300065	11.781	0	11.781	0
11.791	0	11.791	4.24476	11.791	0	11.791	0
11.802	0	11.802	4.18971	11.802	0	11.802	0
11.812	0	11.812	4.110576	11.812	0	11.812	0
11.822	0	11.822	4.031302	11.822	0	11.822	0
11.833	0	11.833	3.940389	11.833	0	11.833	0.023666
11.843	0	11.843	3.837132	11.843	0	11.843	0.426348
11.853	0	11.853	3.721842	11.853	0	11.853	0.853416
11.864	0	11.864	3.606656	11.864	0	11.864	1.30504
11.874	0	11.874	3.479082	11.874	0	11.874	1.757352
11.884	0	11.884	3.351288	11.884	0	11.884	2.246076
11.895	0	11.895	3.21165	11.895	0	11.895	2.73585
11.905	0	11.905	3.07149	11.905	0	11.905	3.23816
11.915	0	11.915	2.93109	11.915	0	11.915	3.753225
11.926	0	11.926	2.77875	11.926	0	11.926	4.26950

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11.936	0	11.936	2.637856	11.936	0	11.936	4.786336
11.946	0	11.946	2.484768	11.946	0	11.946	5.31597
11.957	0	11.957	2.343572	11.957	0	11.957	5.835016
11.967	0	11.967	2.201928	11.967	0	11.967	6.354477
11.977	0	11.977	2.060044	11.977	0	11.977	6.862821
11.987	0	11.987	1.929907	11.987	0	11.987	7.360018
11.998	0	11.998	1.7997	11.998	0	11.998	7.846692
12.008	0	12.008	1.669112	12.008	0	12.008	8.309536
12.018	0	12.018	1.56234	12.018	0	12.018	8.749104
12.029	0	12.029	1.455509	12.029	0	12.029	9.178127
12.039	0	12.039	1.360407	12.039	0	12.039	9.571005
12.049	0	12.049	1.265145	12.049	0	12.049	9.928376
12.059	0	12.059	1.193841	12.059	0	12.059	10.26221
12.07	0	12.07	1.12251	12.07	0	12.07	10.56125
12.08	0	12.08	1.06304	12.08	0	12.08	10.82368
12.09	0	12.09	1.02765	12.09	0	12.09	11.05026
12.1	0	12.1	0.9922	12.1	0	12.1	11.2288
12.111	0	12.111	0.96888	12.111	0	12.111	11.37223
12.121	0	12.121	0.957559	12.121	0	12.121	11.47859
12.131	0	12.131	0.958349	12.131	0	12.131	11.53658
12.141	0	12.141	0.97128	12.141	0	12.141	11.54609
12.151	0	12.151	0.984231	12.151	0	12.151	11.51915

12.162	0	12.162	1.009446	12.162	0	12.162	11.4566
12.172	0	12.172	1.046792	12.172	0	12.172	11.3443
12.182	0	12.182	1.09638	12.182	0	12.182	11.19526
12.192	0	12.192	1.146048	12.192	0	12.192	10.99718
12.202	0	12.202	1.207998	12.202	0	12.202	10.77437
12.213	0	12.213	1.270152	12.213	0	12.213	10.51539
12.223	0	12.223	1.332307	12.223	0	12.223	10.21843
12.233	0	12.233	1.394562	12.233	0	12.233	9.896497
12.243	0	12.243	1.456917	12.243	0	12.243	9.537297
12.253	0	12.253	1.519372	12.253	0	12.253	9.165244
12.264	0	12.264	1.582056	12.264	0	12.264	8.781024
12.274	0	12.274	1.644716	12.274	0	12.274	8.370868
12.284	0	12.284	1.695192	12.284	0	12.284	7.947748
12.294	0	12.294	1.733454	12.294	0	12.294	7.523928
12.304	0	12.304	1.771776	12.304	0	12.304	7.099408
12.314	0	12.314	1.797844	12.314	0	12.314	6.661874
12.325	0	12.325	1.811775	12.325	0	12.325	6.23645
12.335	0	12.335	1.813245	12.335	0	12.335	5.82212
12.345	0	12.345	1.814715	12.345	0	12.345	5.40711
12.355	0	12.355	1.791475	12.355	0	12.355	5.01613
12.365	0	12.365	1.743465	12.365	0	12.365	4.64924
12.375	0	12.375	1.695375	12.375	0	12.375	4.294125

12.385	0	12.385	1.622435	12.385	0	12.385	3.975585
12.395	0	12.395	1.549375	12.395	0	12.395	3.66892
12.406	0	12.406	1.439096	12.406	0.12406	12.406	3.41165
12.416	0	12.416	1.328512	12.416	0.273152	12.416	3.178496
12.426	0	12.426	1.192896	12.426	0.422484	12.426	2.969814
12.436	0	12.436	1.044624	12.436	0.572056	12.436	2.810536
12.446	0	12.446	0.883666	12.446	0.721868	12.446	2.67589
12.456	0	12.456	0.697536	12.456	0.87192	12.456	2.578392
12.466	0	12.466	0.511106	12.466	1.009746	12.466	2.530598
12.476	0	12.476	0.299424	12.476	1.147792	12.476	2.507676
12.486	0	12.486	0.087402	12.486	1.273572	12.486	2.522172
12.496	0	12.496	0	12.496	1.399552	12.496	2.574176
12.506	0	12.506	0	12.506	1.513226	12.506	2.663778
12.516	0	12.516	0	12.516	1.614564	12.516	2.778552
12.527	0	12.527	0	12.527	1.716199	12.527	2.931318
12.537	0	12.537	0	12.537	1.805328	12.537	3.109176
12.547	0	12.547	0	12.547	1.894597	12.547	3.312408
12.557	0	12.557	0	12.557	1.971449	12.557	3.528517
12.567	0	12.567	0	12.567	2.035854	12.567	3.7701
12.577	0	12.577	0	12.577	2.087782	12.577	4.02464
12.587	0	12.587	0	12.587	2.127203	12.587	4.292167
12.597	0	12.597	0	12.597	2.166684	12.597	4.572711

12.607	0	12.607	0	12.607	2.181011	12.607	4.853695
12.617	0	12.617	0	12.617	2.195358	12.617	5.147736
12.627	0	12.627	0	12.627	2.197098	12.627	5.42961
12.637	0	12.637	0	12.637	2.198838	12.637	5.699287
12.647	0	12.647	0	12.647	2.175284	12.647	5.969384
12.657	0	12.657	0	12.657	2.15169	12.657	6.227244
12.667	0	12.667	0	12.667	2.115389	12.667	6.472837
12.677	0	12.677	0	12.677	2.079028	12.677	6.693456
12.687	0	12.687	0	12.687	2.02992	12.687	6.889041
12.697	0	12.697	0	12.697	1.968035	12.697	7.072229
12.707	0	12.707	0	12.707	1.90605	12.707	7.230283
12.717	0	12.717	0	12.717	1.843965	12.717	7.350426
12.727	0	12.727	0	12.727	1.769053	12.727	7.445295
12.737	0	12.737	0	12.737	1.681284	12.737	7.51483
12.747	0	12.747	0	12.747	1.606122	12.747	7.558971
12.757	0	12.757	0	12.757	1.518083	12.757	7.564901
12.767	0	12.767	0	12.767	1.429904	12.767	7.545297
12.777	0	12.777	0	12.777	1.341585	12.777	7.500099
12.787	0	12.787	0	12.787	1.240339	12.787	7.429247
12.797	0	12.797	0	12.797	1.15173	12.797	7.319884
12.807	0	12.807	0	12.807	1.062981	12.807	7.184727
12.817	0	12.817	0	12.817	0.974092	12.817	7.036533

12.827	0	12.827	0	12.827	0.872236	12.827	6.849618
12.836	0	12.836	0	12.836	0.795832	12.836	6.661884
12.846	0	12.846	0	12.846	0.70653	12.846	6.435846
12.856	0	12.856	0	12.856	0.617088	12.856	6.209448
12.866	0	12.866	0	12.866	0.540372	12.866	5.969824
12.876	0	12.876	0	12.876	0.463536	12.876	5.716944
12.886	0	12.886	0	12.886	0.399466	12.886	5.463664
12.896	0	12.896	0	12.896	0.335296	12.896	5.209984
12.906	0	12.906	0	12.906	0.271026	12.906	4.955904
12.916	0	12.916	0	12.916	0.219572	12.916	4.701424
12.926	0	12.926	0	12.926	0.168038	12.926	4.45947
12.936	0	12.936	0.310464	12.936	0.12936	12.936	4.217136
12.946	0	12.946	0.634354	12.946	0.090622	12.946	4.000314
12.955	0	12.955	0.945715	12.955	0.064775	12.955	3.795815
12.965	0	12.965	1.257605	12.965	0.038895	12.965	3.60427
12.975	0	12.975	1.557	12.975	0.012975	12.975	3.438375
12.985	0	12.985	1.856855	12.985	0.012985	12.985	3.29819
12.995	0	12.995	2.144175	12.995	0	12.995	3.183775
13.005	0	13.005	2.41893	13.005	0	13.005	3.09519
13.015	0	13.015	2.694105	13.015	0	13.015	3.032495
13.025	0	13.025	2.94365	13.025	0	13.025	2.99575
13.034	0	13.034	3.19333	13.034	0	13.034	2.984786
13.044	0	13.044	3.417528	13.044	0	13.044	3.013164

13.054	0	13.054	3.642066	13.054	0	13.054	3.054636
13.064	0	13.064	3.840816	13.064	0	13.064	3.148424
13.074	0	13.074	4.039866	13.074	0	13.074	3.255426
13.084	0	13.084	4.213048	13.084	0	13.084	3.388756
13.094	0	13.094	4.373396	13.094	0	13.094	3.548474
13.103	0	13.103	4.520535	13.103	0	13.103	3.734355
13.113	0	13.113	4.668228	13.113	0	13.113	3.947013
13.123	0	13.123	4.789895	13.123	0	13.123	4.173114
13.133	0	13.133	4.898609	13.133	0	13.133	4.425821
13.143	0	13.143	5.007483	13.143	0	13.143	4.678908
13.153	0	13.153	5.090211	13.153	0	13.153	4.958681
13.162	0	13.162	5.172666	13.162	0	13.162	5.238476
13.172	0	13.172	5.242456	13.172	0	13.172	5.53224
13.182	0	13.182	5.299164	13.182	0	13.182	5.826444
13.192	0	13.192	5.355952	13.192	0	13.192	6.121088
13.202	0	13.202	5.399618	13.202	0	13.202	6.416172
13.211	0	13.211	5.442932	13.211	0	13.211	6.697977
13.221	0	13.221	5.473494	13.221	0	13.221	6.980688
13.231	0	13.231	5.490865	13.231	0	13.231	7.237357
13.241	0	13.241	5.508256	13.241	0	13.241	7.494406
13.251	0	13.251	5.525667	13.251	0	13.251	7.725333
13.26	0	13.26	5.54268	13.26	0	13.26	7.92948
13.27	0	13.27	5.54686	13.27	0	13.27	8.12124

13.28	0	13.28	5.55104	13.28	0	13.28	8.28672
13.29	0	13.29	5.55522	13.29	0	13.29	8.42586
13.299	0	13.299	5.545683	13.299	0	13.299	8.537958
13.309	0	13.309	5.549853	13.309	0	13.309	8.610923
13.319	0	13.319	5.540704	13.319	0	13.319	8.65735
13.329	0	13.329	5.531535	13.329	0	13.329	8.66385
13.338	0	13.338	5.521932	13.338	0	13.338	8.643024
13.348	0	13.348	5.512724	13.348	0	13.348	8.596112
13.358	0	13.358	5.490138	13.358	0	13.358	8.509046
13.368	0	13.368	5.467512	13.368	0	13.368	8.381736
13.377	0	13.377	5.444439	13.377	0	13.377	8.226855
13.387	0	13.387	5.421735	13.387	0	13.387	8.0322
13.397	0	13.397	5.398991	13.397	0	13.397	7.810451
13.407	0	13.407	5.3628	13.407	0	13.407	7.548141
13.416	0	13.416	5.326152	13.416	0	13.416	7.258056
13.426	0	13.426	5.289844	13.426	0	13.426	6.941242
13.436	0	13.436	5.253476	13.436	0	13.436	6.597076
13.445	0	13.445	5.203215	13.445	0	13.445	6.225035
13.455	0	13.455	5.13981	13.455	0	13.455	5.83947
13.465	0	13.465	5.08977	13.465	0	13.465	5.426395
13.475	0	13.475	5.0127	13.475	0	13.475	4.98575
13.484	0	13.484	4.948628	13.484	0	13.484	4.544108
13.494	0	13.494	4.871334	13.494	0	13.494	4.075188
13.504	0	13.504	4.780416	13.504	0	13.504	3.605568

13.513	0	13.513	4.68901 1	13.513	0	13.513	3.12150 3
13.523	0	13.523	4.59782	13.523	0	13.523	2.62346 2
13.533	0	13.533	4.49295 6	13.533	0	13.533	2.12468 1
13.542	0	13.542	4.38760 8	13.542	0	13.542	1.63858 2
13.552	0	13.552	4.26888	13.552	0	13.552	1.13836 8
13.562	0	13.562	4.13641	13.562	0	13.562	0.65097 6
13.571	0	13.571	4.01701 6	13.571	0	13.571	0.17642 3
13.581	0	13.581	3.88416 6	13.581	0	13.581	0
13.591	0	13.591	3.73752 5	13.591	0	13.591	0
13.6	0	13.6	3.5904	13.6	0	13.6	0
13.61	0	13.61	3.44333	13.61	0	13.61	0
13.62	0	13.62	3.29604	13.62	0	13.62	0
13.629	0	13.629	3.13467	13.629	0	13.629	0
13.639	0	13.639	2.97330 2	13.639	0	13.639	0
13.648	0	13.648	2.81148 8	13.648	0	13.648	0
13.658	0	13.658	2.64965 2	13.658	0	13.658	0
13.668	0	13.668	2.48757 6	13.668	0	13.668	0
13.677	0	13.677	2.32509	13.677	0	13.677	0
13.687	0	13.687	2.16254 6	13.687	0	13.687	0
13.697	0	13.697	1.99976 2	13.697	0	13.697	0
13.706	0	13.706	1.85031	13.706	0	13.706	0
13.716	0	13.716	1.68706 8	13.716	0	13.716	0
13.725	0	13.725	1.5372	13.725	0	13.725	0
13.735	0	13.735	1.38723 5	13.735	0	13.735	0
13.745	0	13.745	1.25079 5	13.745	0	13.745	0
13.754	0	13.754	1.11407	13.754	0	13.754	0

			4				
13.764	0	13.764	0.977244	13.764	0	13.764	0
13.773	0	13.773	0.853926	13.773	0	13.773	0
13.783	0	13.783	0.730499	13.783	0	13.783	0
13.793	0	13.793	0.620685	13.793	0	13.793	0
13.802	0	13.802	0.524476	13.802	0	13.802	0
13.812	0	13.812	0.428172	13.812	0	13.812	0
13.821	0	13.821	0.345525	13.821	0	13.821	0
13.831	0	13.831	0.262789	13.831	0	13.831	0
13.841	0	13.841	0.193774	13.841	0	13.841	0
13.85	0	13.85	0.1385	13.85	0	13.85	0
13.86	0	13.86	0.09702	13.86	0	13.86	0
13.869	0	13.869	0.055476	13.869	0	13.869	0
13.879	0	13.879	0.027758	13.879	0	13.879	0
13.888	0	13.888	0.013888	13.888	0	13.888	0
13.898	0	13.898	0	13.898	0	13.898	0
13.907	0	13.907	0	13.907	0	13.907	0
13.917	0	13.917	0	13.917	0	13.917	0
13.926	0	13.926	0	13.926	0	13.926	0
13.936	0	13.936	0	13.936	0	13.936	0
13.946	0	13.946	0	13.946	0	13.946	0
13.955	0	13.955	0	13.955	0	13.955	0.16746
13.965	0	13.965	0	13.965	0	13.965	0.53067
13.974	0	13.974	0	13.974	0	13.974	0.894336
13.984	0	13.984	0	13.984	0	13.984	1.25856
13.993	0	13.993	0	13.993	0	13.993	1.595202
14.003	0	14.003	0	14.003	0	14.003	1.946417
14.012	0	14.012	0	14.012	0	14.012	2.269944

14.022	0	14.022	0	14.022	0	14.022	2.580048
14.031	0	14.031	0	14.031	0	14.031	2.890386
14.041	0	14.041	0	14.041	0	14.041	3.173266
14.05	0	14.05	0	14.05	0	14.05	3.44225
14.06	0	14.06	0	14.06	0	14.06	3.69778
14.069	0	14.069	0	14.069	0	14.069	3.925251
14.079	0	14.079	0	14.079	0	14.079	4.139226
14.088	0	14.088	0	14.088	0	14.088	4.325016
14.098	0	14.098	0	14.098	0	14.098	4.497262
14.107	0	14.107	0	14.107	0	14.107	4.641203
14.117	0	14.117	0	14.117	0	14.117	4.771546
14.126	0	14.126	0	14.126	0	14.126	4.87347
14.136	0	14.136	0	14.136	0	14.136	4.9476
14.145	0	14.145	0	14.145	0	14.145	5.00733
14.154	0	14.154	0	14.154	0	14.154	5.038824
14.164	0	14.164	0	14.164	0	14.164	5.056548
14.173	0	14.173	0	14.173	0	14.173	5.045588
14.183	0	14.183	0	14.183	0	14.183	5.020782
14.192	0	14.192	0	14.192	0	14.192	4.9672
14.202	0	14.202	0	14.202	0	14.202	4.885488
14.211	0	14.211	0	14.211	0	14.211	4.803318
14.221	0	14.221	0	14.221	0	14.221	4.69293
14.23	0	14.23	0	14.23	0	14.23	4.56783
14.239	0	14.239	0	14.239	0	14.239	4.428329
14.249	0	14.249	0	14.249	0	14.249	4.260451
14.258	0	14.258	0	14.258	0	14.258	4.092046

14.268	0	14.268	0	14.268	0	14.268	3.909432
14.277	0	14.277	0	14.277	0	14.277	3.697743
14.287	0	14.287	0	14.287	0	14.287	3.486028
14.296	0	14.296	0	14.296	0	14.296	3.273784
14.305	0	14.305	0	14.305	0	14.305	3.03266
14.315	0	14.315	0	14.315	0	14.315	2.791425
14.324	0	14.324	0	14.324	0	14.324	2.549672
14.334	0	14.334	0	14.334	0	14.334	2.29344
14.343	0	14.343	0	14.343	0	14.343	2.022363
14.352	0	14.352	0	14.352	0	14.352	1.765296
14.362	0	14.362	0	14.362	0	14.362	1.493648
14.371	0	14.371	0	14.371	0	14.371	1.221535
14.381	0	14.381	0	14.381	0	14.381	0.934765
14.39	0	14.39	0	14.39	0	14.39	0.66194
14.399	0	14.399	0	14.399	0	14.399	0.374374
14.409	0	14.409	0	14.409	0	14.409	0.230544
14.418	0	14.418	0	14.418	0	14.418	0.230688

Appendix 3 – Data on the dependences of neutron energy on the density of the neutron flux at the measurement points with the dosimeter-radiometer AT-1117M

Measuring point 1.6		Measuring point 1.8		Measuring point 2.6		Measuring point 3.6	
Neutron energy. MeV	Neutron flux density. $cm^{-2}s^{-1}$	Neutron energy. MeV	Neutron flux density. $cm^{-2}s^{-1}$	Neutron energy. MeV	Neutron flux density. $cm^{-2}s^{-1}$	Neutron energy. MeV	Neutron flux density. $cm^{-2}s^{-1}$
$1.00 \cdot 10^{-9}$	0.005572	$1.00 \cdot 10^{-9}$	0.041303	$1.00 \cdot 10^{-9}$	0.009799	$1.00 \cdot 10^{-9}$	0.002598
$2.15 \cdot 10^{-9}$	0.024641	$2.15 \cdot 10^{-9}$	0.182945	$2.15 \cdot 10^{-9}$	0.043356	$2.15 \cdot 10^{-9}$	0.011485
$4.64 \cdot 10^{-9}$	0.104307	$4.64 \cdot 10^{-9}$	0.777083	$4.64 \cdot 10^{-9}$	0.183623	$4.64 \cdot 10^{-9}$	0.048567
$1.00 \cdot 10^{-8}$	0.394729	$1.00 \cdot 10^{-8}$	2.964948	$1.00 \cdot 10^{-8}$	0.695408	$1.00 \cdot 10^{-8}$	0.183339

$2.15\cdot10^{-8}$	1.180861	$2.15\cdot10^{-8}$	9.06798	$2.15\cdot10^{-8}$	2.083755	$2.15\cdot10^{-8}$	0.544757
$4.64\cdot10^{-8}$	2.202948	$4.64\cdot10^{-8}$	18.17815	$4.64\cdot10^{-8}$	3.908515	$4.64\cdot10^{-8}$	0.992599
$1.00\cdot10^{-7}$	1.732751	$1.00\cdot10^{-7}$	18.31904	$1.00\cdot10^{-7}$	3.149041	$1.00\cdot10^{-7}$	0.705464
$2.15\cdot10^{-7}$	0.804227	$2.15\cdot10^{-7}$	12.59619	$2.15\cdot10^{-7}$	1.552966	$2.15\cdot10^{-7}$	0.251151
$4.64\cdot10^{-7}$	0.751102	$4.64\cdot10^{-7}$	12.23133	$4.64\cdot10^{-7}$	1.481357	$4.64\cdot10^{-7}$	0.226337
$1.00\cdot10^{-6}$	0.751025	$1.00\cdot10^{-6}$	12.24625	$1.00\cdot10^{-6}$	1.503334	$1.00\cdot10^{-6}$	0.226511
$2.15\cdot10^{-6}$	0.750955	$2.15\cdot10^{-6}$	12.26122	$2.15\cdot10^{-6}$	1.525588	$2.15\cdot10^{-6}$	0.226678
$4.64\cdot10^{-6}$	0.750868	$4.64\cdot10^{-6}$	12.27624	$4.64\cdot10^{-6}$	1.548281	$4.64\cdot10^{-6}$	0.226819
$1.00\cdot10^{-5}$	0.750749	$1.00\cdot10^{-5}$	12.29115	$1.00\cdot10^{-5}$	1.571263	$1.00\cdot10^{-5}$	0.226901
$2.15\cdot10^{-5}$	0.75056	$2.15\cdot10^{-5}$	12.30582	$2.15\cdot10^{-5}$	1.594496	$2.15\cdot10^{-5}$	0.226857
$4.64\cdot10^{-5}$	0.750217	$4.64\cdot10^{-5}$	12.32014	$4.64\cdot10^{-5}$	1.618155	$4.64\cdot10^{-5}$	0.22654
$1.00\cdot10^{-4}$	0.749546	$1.00\cdot10^{-4}$	12.33348	$1.00\cdot10^{-4}$	1.642044	$1.00\cdot10^{-4}$	0.22564
$2.15\cdot10^{-4}$	0.748174	$2.15\cdot10^{-4}$	12.3447	$2.15\cdot10^{-4}$	1.66604	$2.15\cdot10^{-4}$	0.223502
$4.64\cdot10^{-4}$	0.745278	$4.64\cdot10^{-4}$	12.35149	$4.64\cdot10^{-4}$	1.690138	$4.64\cdot10^{-4}$	0.218729
$1.00\cdot10^{-3}$	0.739147	$1.00\cdot10^{-3}$	12.34855	$1.00\cdot10^{-3}$	1.713731	$1.00\cdot10^{-3}$	0.208594
$2.15\cdot10^{-3}$	0.726227	$2.15\cdot10^{-3}$	12.32484	$2.15\cdot10^{-3}$	1.735825	$2.15\cdot10^{-3}$	0.188224
$4.64\cdot10^{-3}$	0.699085	$4.64\cdot10^{-3}$	12.25627	$4.64\cdot10^{-3}$	1.754478	$4.64\cdot10^{-3}$	0.150531
$1.00\cdot10^{-2}$	0.644108	$1.00\cdot10^{-2}$	12.09291	$1.00\cdot10^{-2}$	1.765012	$1.00\cdot10^{-2}$	0.092965
$1.99\cdot10^{-2}$	0.553726	$1.99\cdot10^{-2}$	11.78363	$1.99\cdot10^{-2}$	1.759959	$1.99\cdot10^{-2}$	0.038164
$3.16\cdot10^{-2}$	0.463145	$3.16\cdot10^{-2}$	11.42277	$3.16\cdot10^{-2}$	1.742511	$3.16\cdot10^{-2}$	0.013376
$5.01\cdot10^{-2}$	0.349218	$5.01\cdot10^{-2}$	10.87193	$5.01\cdot10^{-2}$	1.707012	$5.01\cdot10^{-2}$	0.002694
$1.00\cdot10^{-1}$	0.163259	$1.00\cdot10^{-1}$	9.519396	$1.00\cdot10^{-1}$	1.601556	$1.00\cdot10^{-1}$	0.000639
$1.99\cdot10^{-1}$	0.037023	$1.99\cdot10^{-1}$	7.364018	$1.99\cdot10^{-1}$	1.409021	$1.99\cdot10^{-1}$	0.002
$3.16\cdot10^{-1}$	0.008582	$3.16\cdot10^{-1}$	5.548837	$3.16\cdot10^{-1}$	1.231918	$3.16\cdot10^{-1}$	0.004324
$5.01\cdot10^{-1}$	0.006219	$5.01\cdot10^{-1}$	3.829391	$5.01\cdot10^{-1}$	1.055885	$5.01\cdot10^{-1}$	0.00901
1.00	0.018196	1.00	2.842949	1.00	1.00955	1.00	0.024255
1.99	0.043924	1.99	4.955561	1.99	1.57042	1.99	0.0508
3.16	0.061704	3.16	6.884507	3.16	2.085505	3.16	0.064859
5.01	0.061502	5.01	6.856676	5.01	2.042562	5.01	0.058765
10.0	0.020214	10.0	2.252021	10.0	0.658377	10.0	0.01673
15.8	0.002777	15.8	0.309196	15.8	0.089236	15.8	0.002088