Московский государственный технический университет
имени Н.Э. Баумана

Методические указания

Т.А. Фуфурина

ОБУЧЕНИЕ ЧТЕНИЮ ЛИТЕРАТУРЫ НА АНГЛИЙСКОМ ЯЗЫКЕ ПО СПЕЦИАЛЬНОСТИ «ЯДЕРНЫЕ РЕАКТОРЫ»

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В методических указаниях содержатся оригинальные тексты на английском языке для аудиторной и самостоятельной работы, знакомящие студентов с наиболее часто встречающейся терминологией в области ядерных энергетических установок.

Пособие состоит из четырех уроков (Units), в каждом из которых представлены тексты на английском языке, даны упражнения и задания, направленные на закрепление лексико-грамматического материала, необходимого для понимания и перевода научно-технической литературы на английском языке, а также для развития навыков разговорной речи. Каждый урок завершается заданием на проверку знания лексики данного урока.

Для студентов старших курсов, учащихся магистратуры и аспирантов факультета «Энергомашиностроение» МГТУ им. Н.Э. Баумана, обучающихся по специальности «Ядерные реакторы».

Рекомендовано Учебно-методической комиссией НУК ФН МГТУ им. Н.Э. Баумана.

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ПРЕДИСЛОВИЕ

В методических указаниях представлены оригинальные тексты из английской и американской научно-технической литературы для аудиторной и самостоятельной работы студентов старших курсов, обучающихся по специальности «Ядерные реакторы».

Методические указания состоят из четырех уроков (Units), каждый из которых содержит три текста. Все тексты предназначены для обучения различным видам чтения. Первый текст является основным и подлежит тщательной проработке. Остальные тексты служат развитию навыков чтения, понимания и извлечения необходимой информации, а также навыков ведения беседы на английском языке по тематике, представляющей профессиональный интерес. Каждый урок завершается заданием (Progress Test) на проверку знания лексики данного урока.

В методические указания также включены поурочные словари, содержащие активную лексику, главным образом терминологию, лексико-грамматические упражнения и задания, позволяющие развить навыки перевода литературы по специальности с английского языка на русский, овладеть ключевой терминологией, закрепить некоторые грамматические конструкции, характерные для научно-технической литературы.

Целью работы является развитие и закрепление навыков понимания, осмысления, перевода и аннотирования литературы на английском языке по изучаемой специальности, а также навыков устной речи, связанной с соответствующей тематикой.

Пособие предназначено для студентов старших курсов, учащихся магистратуры и аспирантов факультета «Энергомашиностроение» МГТУ им. Н.Э. Баумана, обучающихся по специальности «Ядерные реакторы».

UNIT I

New Words and Word Combinations

absorb *v*	поглощать
containment *n*	защитная оболочка
control rod	регулирующий стержень
controlled reaction	управляемая реакция
coolant *n*	теплоноситель
Doppler broadening	допплеровское уширение
emergency shutdown	аварийная остановка (реактора)
enrichment *n*	обогащение
fuel pellet	топливная таблетка
fusion power	термоядерная энергия
heat insulation	теплоизоляция
neutron moderator	замедлитель нейтронов
nuclear fission	деление ядер
prompt critical	мгновенно критический
reactor core	активная зона реактора
refined uranium	очищенный уран
released neutron	высвободившийся нейтрон
reprocessed fuel	переработанное топливо
self-sustaining *adj*	самоподдерживающийся
subcritical reactor	подкритический реактор

1. Read and translate Text IA using a dictionary.

Text IA. Nuclear Reactor

A nuclear reactor is a device in which chain reactions are initiated, controlled, and sustained at a steady rate (as opposed to a nuclear explosion, where the chain reaction occurs in a split second). Nuclear reactors are used for many purposes, but the most significant current uses are for the generation of electrical power and, in rare cases, for the production of plutonium for use in nuclear weapons. Currently all commercial nuclear reactors are based on nuclear fission, and are considered problematic by some for their safety and health risks. Fusion power is an experimental technology based on nuclear fusion instead of fission.

All commercial nuclear reactors produce heat through nuclear fission.

In this process, the nucleus of an element such as uranium splits into smaller atoms. This occurs naturally in radioactive elements, but it can be induced artificially by making some atoms absorb a neutron. This causes the nucleus to become unstable and makes it split apart very quickly.

The fission process for a uranium atom yields two smaller atoms, one to three fast-moving free neutrons, and energy. Uranium fission therefore releases more neutrons than it requires, and the reaction can become self sustaining if conditions are appropriate. This is called a chain reaction. A chain reaction will occur if, during fission, the neutrons emitted come into contact in turn with fissile nuclei which, by splitting, release further neutrons. In order for this to happen, it is necessary to reduce both the speed of the neutrons and have a minimal density of fissile material (critical mass).

The neutrons released by fission are moving quickly. Such "fast neutrons" are not easily absorbed by fissionable nuclei. Some reactors are designed to work with these neutrons, but most reactors use a neutron moderator to slow these neutrons down so that they are more easily absorbed. Such neutrons are often slowed until they are in thermal equilibrium with the reactor core; as a result, they are called thermal neutrons (or slow neutrons).

The amount of heat produced by a reactor is crucial parameter. It may be controlled by adjusting the amount of neutron moderator in the reactor core, control rods consisting of neutron absorbers may be used to control the output, or the physical arrangement of the fuel may be changed (often by thermal expansion or contraction). The Doppler broadening effect also serves to reduce the rate of fission as the temperature increases. Many reactors use several methods, both for control and for emergency shutdown.

Nuclear reactors are divided into two classes, depending on the energy of neutrons that are used to sustain the fission chain reaction:

• Reactors with thermal neutrons in which the density of fissile material remains low (enrichment of U-235 to approximately 3 % or 4 % as compared to 0.7 % in its natural state). It is necessary, therefore, to slow down the neutrons in order to investigate the chain reaction (facilitate the capture of neutrons) which would imply using a material which slows down neutrons without absorbing them too much.

• Reactors with fast neutrons in which the density of fissile material is high, which obviates the need to slow down the neutrons (principle of fast-breeder reactors.

There are several different types of reactors such as: Pressurized Water reactor (PWR), Boiling Water Reactor (BWR), Advanced Gas-Cooled Reactor (AGR), Light Water Graphite Reactor (LWGR), Fast Neutron Reactor (FBR), etc.

A nuclear reactor is generally composed of:

• The core, which holds the fuel and possibly a moderator to slow down the neutrons.

• A system of control rods, designed to regulate the chain reaction by absorbing neutrons.

• A coolant. A liquid or a gas circulating through the core is used to transfer the heat from it.

• A heat-insulation system: A turbine in the case of a submarine reactor for propulsion, generator for electricity production as with a plant connected to the grid.

• A moderator. This is a material which slows down the neutrons released from fission. PWR reactor uses ordinary water as both coolant and moderator.

• Containment. This is the structure around the reactor core which is designed to protect it from outside intrusion or from the effects of radiation or any malfunction inside. It is typically a metre-thick concrete and steel structure, etc.

All nuclear reactors are the result of several compromises. It is necessary to use either highly enriched fuel or else a moderator. It is necessary to find a moderator which is effective at slowing down the neutrons without absorbing them too much. In practice, nuclear reactors are defined by three factors: fuel, coolant and moderator.

Thermal reactors generally depend on refined and enriched uranium. Some nuclear reactors can operate with a mixture of plutonium and uranium. The process by which uranium ore is mined, processed, enriched, used, possibly reprocessed and disposed of is known as the nuclear fuel cycle.

Under 1 % of the uranium found in nature is the easily fissionable U-235 isotope and as a result most reactor designs require enriched fuel. Enrichment involves increasing the percentage of U-235 and is usually done by means of gaseous diffusion or gas centrifuge. The enriched fuel is then converted into uranium dioxide powder, which is pressed and fired into pellet form. These pellets are stacked into tubes which are then sealed and called fuel rods. Many of these fuel rods are used in each nuclear reactor.

Most BWR and PWR commercial reactors use uranium enriched to about 4 % U-235, and some commercial reactors with a high neutron economy do not require the fuel to be enriched at all (that is, they can use natural uranium).It should be noted that fissionable U-235 and non-fissionable U-238 are both used in the fission process.

Nuclear fuel is any material that can be consumed to derive nuclear energy, by analogy to chemical fuel that is burned to derive energy. The most common type of nuclear fuel is heavy fissile elements that can be made to undergo nuclear fission chain reactions in a nuclear fission reactor; nuclear fuel can refer to the material or to physical objects (for example fuel bundles composed of fuel rods) composed of the fuel material, perhaps mixed with structural, neutron moderating, or neutron reflecting materials. The most common fissile nuclear fuels are U-235 and

Pu-239, and the actions of mining, refining, purifying, using, and ultimately disposing of these elements together make up the nuclear fuel cycle, which is important for its relevance to nuclear power generation and nuclear weapons.

2. Answer the questions.

1. What are nuclear reactors used for?
2. What process is used in nuclear reactor to produce heat?
3. When will a chain reaction occur?
4. Why do we call neutrons “thermal neutrons”?
5. What is a crucial parameter? How can it be controlled?
6. Does the Doppler broadening effect serve to increase or to reduce the rate of fission?
7. What is a nuclear reactor composed of?
8. What material is used to derive nuclear energy?

3. Describe the reactor fuel from the point of view of its pre-use, in-use and post-use application.

4. Match the words (1–6) to the descriptions (a–f).

1) nuclear reactor	a) a process in which the nucleus of an element splits into atoms
2) nuclear fission	b) any rod used to control the reactivity of a nuclear reactor
3) chain reaction	c) fission events that occur immediately for the reaction to be self-sustaining
4) prompt critical	d) a process by which uranium ore is mined, processed, enriched, used, possibly reprocessed and disposed of
5) control rod	e) a device in which chain reactions are initiated, controlled and self-sustained
6) nuclear fuel cycle	f) a multistage nuclear reaction in which the release of neutrons from the splitting of one atom leads to the splitting of others

5. Complete the sentences using the words from the box.

Coolant, fission, generation, enrichment, neutron moderator, controlling

1. The principal peaceful application of nuclear energy is that of electricity _________.
2. Thermal reactor operation depends on the refined and enriched fuel, the ________ of which is usually done by means of gaseous diffusion or gas centrifuge.
3. The principle behind a nuclear power plant consists of ___________ the chain reaction in order to obtain a certain quantity of energy over a certain duration.
4. _____________ takes place when a heavy nucleus absorbs a neutron.
5. Most reactors use a ______ _______ to slow these neutrons down so that they are more easily absorbed.
6. Water can be used in most nuclear reactors as a ___________ either in the pressurized liquid form or by boiling into steam.

6. Translate the sentences from Russian into English.

1. Ядерный реактор — устройство, в котором возникают самоподдерживающиеся ядерные цепные реакции.
2. Ядерный реактор производит теплоту при делении ядер.
3. В большинстве ядерных реакторов используется замедлитель нейтронов с целью более легкого их поглощения.
4. Ядерные реакторы подразделяются на два класса в зависимости от энергии нейтронов.
5. Ядерный реактор состоит из: активной зоны, регулирующих стержней, теплоносителя, замедлителя, защитной оболочки реактора, систем аварийного охлаждения, и др.
6. Вода под высоким давлением используется в качестве теплоносителя и замедлителя.

7. Ядерный реактор охлаждается циркулирующей водой, которая проходит через систему труб, и нагревается до высокой температуры.

8. Тепло отводится из реактора водой, протекающей в закрытом контуре высокого давления.

7. Translate the sentences paying attention to the Complex Subject.

1. Nuclear energy is considered to be an alternative to fossil fuel in the context of polices to reduce emissions of greenhouse gases.
2. Fission is thought to take place when a heavy nucleus absorbs a neutron thereby creating an unstable edifice which splits into two lighter nuclei.
3. The potential technological process is said to be a key element of the future of nuclear energy.
4. A nuclear melt down is thought to be occurred if the reactor losses its coolant.
5. The residual heat and the heat produced from the decay of the fission products are considered to be enough to drive the core's temperature up even if nuclear chain reaction stops.
6. The spent fuel rods are believed to be the most radioactive of all nuclear wastes.
7. Apart from hydropower, nuclear energy proves to be the only technology available today for the intensive production of energy without CO_2.
8. These experiments are likely to have been made in suitable conditions.
9. This new approach to the problem discussed appears to be the most satisfactory.
10. This reaction was not expected to start at low temperatures.

8. Read and translate Text IB.

Text IB. Reactor Operation

A nuclear reactor is designed to carry out nuclear fission reactions on a large scale. This produces heat, fission products, and intense neutron radiation. In nuclear power plant, that heat is used to do useful work. Some reactors, whether experimental or military, are designed for making use of the generated heat, as their goal is to make use of the neutron to transmute elements. In either case, for all current nuclear reactors, it is essential that a nuclear chain reaction be continually sustained.

In a sustained nuclear chain reaction, the fission of a single fuel nucleus releases a few neutrons. These neutrons initially carry a great deal of energy (and are therefore called fast neutrons). These neutrons may be captured immediately by another fuel nucleus, or they may interact with a neutron moderator or a neutron absorber. The likelihood that a fast-moving neutron is captured by a fuel nucleus is relatively low, so it is often necessary to slow down the neutrons. This is done by allowing the neutrons to scatter off nuclei of a neutron moderator. After a few such scattering events, the neutron radiation has a thermal energy spectrum (that is, they are moving with the same average energy as a gas at the same temperature as the reactor core) and is much more easily captured by a fuel nucleus.

When a neutron is captured by a fuel nucleus, the nucleus may undergo fission immediately, it may remain in an unstable state for a short while before undergoing fission, or it may fail to undergo fission at all. Fission events that occur immediately are called “prompt” fission events, and if there are enough prompt events for the reaction to be self-sustaining without the delayed fission events, then the reactor is said to be prompt critical. In such a situation, the amount of fission in the reactor will grow exponentially and very quickly; the result would be large explosion. Thus, a stable nuclear reactor must be maintained in a critical but not prompt critical state. Controls are also essential to ensure that the temperature does not rise so high that the reactor is damaged or destroyed.

A nuclear reactor is controlled by adjusting the configuration of neutron absorbers in and around the core, the configuration of the neutron moderator, and sometimes the configuration of the fuel itself. The most common arrangement is to include neutron-absorbing control rods which can be partially inserted into the reactor in order to damp its reaction. Such control rods normally require sophisticated monitoring equipment, so a number of advanced reactor designs (such as pebble-bed reactor) have tried to build in passive safety systems which require no action by electronic, mechanical, or human agents to prevent plant overheating.

In any nuclear reactor, some sort of cooling is necessary. In a nuclear power plant, the cooling system must be designed so that it can make use of the heat released. Most nuclear reactors use water as a coolant, either in a pressurized liquid form or by boiling into steam. Since water acts as a moderator, fast reactors cannot be cooled with water. Molten sodium or sodium salts are in current use. Reactor designed for transmutation only may simple release the heat to the environment.

9. Find the meanings of the following word combinations in Russian (a) corresponding to those in English (b):

а) Интенсивное нейтронное излучение, непрерывно-поддерживаемая ядерная цепная реакция, захват нейтронов, средняя энергия, замедление нейтронов, в неустойчивом состоянии, управление ядерным реактором, мгновенно критический реактор, нейтронно-поглощающие регулирующие стержни, выделенная теплота, реактор с шаровой засыпкой, затухание реакции, усовершенствованная конструкция реактора, пассивные системы безопасности, перегрев установки.

b) Reaction damping, prompt critical reactor, plant overheating, intense neutron radiation, neutron capture, nuclear reactor control, continually sustained nuclear chain reaction, average energy, slowing down of neutrons, advanced reactor design, generated heat, neutron-absorbing control rods, pebble-bed reactor, passive safety systems, in an unstable state.

10. Make the following words negative by adding the prefixes in-, im- or un-:

1) effective ____________	6) reasonable ___________
2) economical __________	7) possible _____________
3) predictable __________	8) active ______________
4) essential ____________	9) reliable _____________
5) probable ____________	10) sufficient ___________

11. Complete the following sentences.

1. Nuclear reactors are designed to …
2. A nuclear reactor produces …
3. …for all current nuclear reactors, it is essential that a nuclear chain reaction …
4. These neutrons may be captured immediately by…
5. Fission events that occur immediately are called …
6. Thus, a stable nuclear reactor must be maintained in …
7. Controls are essential to ensure that the temperature …
8. A nuclear reactor is controlled by …
9. Such control rods normally require …
10. Most nuclear reactors use water as a …

12. Discuss the reactor operation in pairs. Ask as many questions as possible to each other and answer them.

13. Read and translate Text 1C.

Text IC. Reactor Safety

By regulation, as part of the design of any nuclear reactor provisions must be made for operator errors or failure of critical equipment. For this reason the "Defense in Depth" concept is employed to ensure operability of all systems when required for safety. All systems in nuclear plants have three main safety objectives:

- Control of Reactivity (ability to control the amount flux in the fuel either mechanically or chemically),
- Maintenance of Core Cooling (maintaining an adequate supply and backup supply of coolant to the core region) and
- Maintenance of Barrier to Release of Radiation (fuel cladding, primary barrier, containment and attenuation devices).

Where Systems, Structures and Components (SSC) are required to perform any duties supporting the three safety functions, they are provided with frequent inspection, operational or functional tests, and increased design, purchased and repair scrutiny as part of a Quality Assurance plan. Part of the design of these SSC includes redundancy (having multiple backup components), provision of independent systems (such as a requirement to have two or more separate systems performing the same function in parallel) "voting" on an interpretation of a signal, fail-safe design (knowing how a SSC will fail and what effect it will have on companion SSC) monitoring instrumentation and protection against "Common Mode Failure". Common Mode Failure prevents a single failure from affecting both "trains"or systems of independent, redundant equipment. Engineering performance is tested on a frequent basis (surveillance) to provide assurance of readiness to perform its designed function. It should be noted that many of these same design features are mandated on commercial airliners.

On detection of process (pressure, temperature, radiation, flow, etc.) indications outside of a normal range an alarm will sound and be "acknowledged" in the control room, where an operator makes adjustments. If the alarming parameters exceed set points further, the reactor, turbine or generator may provide a fault signal which automatically places the system in a safer (lower energy) mode and may terminate operations without operator control. In case of a generator or turbine fault, steam will be limited or shut off and the turbine will slow. If the problem is not corrected quickly, a SCRAM will occur automatically inserting the control rods into the reactor core and slowing the neutron flux by over 99% in seconds. The plant can be restarted, but only after an investigation is completed.

14. Discuss why the "Defense in Depth" concept is employed to ensure operability of all systems. Express your opinion, using the following words and phrases from the box.

In the first place, for this reason, secondly, both … and, furthermore, it should be noted that, in addition, if the problem is not corrected quickly, I believe, in my view.

PROGRESS TEST 1

Task 1. Complete the sentences using the words from the box and translate the text from English into Russian without a dictionary.

Neutron emission, criticality, delayed neutron, nuclear meltdown, neutron poison, fissions, power output, critical mass

Text 1. Reactor control

The power output of the nuclear reactor is adjusted by controlling how many neutrons are able to create more ___________.

Control rods that are made of a ___________ are used to absorb neutrons. Absorbing more neutrons in a control rod means that there are fewer neutrons available to cause fission, so pushing the control rod deeper into the reactor will reduce its ___________, and extracting the control rod will increase it.

At the first level of control in all nuclear reactors, a process of ___________ emission by a number of neutron-rich fission isotopes is an important physical process. These delayed neutrons account for about 0.65 % of the total neutrons produced in fission, with the remainder (termed "prompt neutrons") released immediately upon fission. The fission products which produce delayed neutrons have half lives for their decay by ___________ that range from milliseconds to as long as several minutes. Keeping the reactor in the zone of chain-reactivity where delayed neutrons are necessary to achieve a ___________ state, allows time for mechanical devices or human operators to have time to control a chain reaction in "real time"; otherwise the time between achievement of ___________ and ___________ as a result of an exponential power surge from the normal nuclear chain reaction, would be too short to allow for intervention.

UNIT II

New Words and Word Combinations

advanced gas-cooled reactor	усовершенствованный газоохлаждаемый реактор
collision *n*	столкновение
fast-breeder reactor	реактор-размножитель на быстрых нейтронах
film boiling	пленочное кипение
fuel cladding	оболочка топлива
light-water graphite-moderated reactor	легководный реактор с графитовым замедлителем
ordinary water	обычная вода
pressurized water reactor	реактор с водой под давлением
primary coolant loop	первый контур
reactor vessel	корпус реактора
safety feature	особенности системы обеспечения безопасности
saturated steam	насыщенный пар
secondary coolant	теплоноситель второго контура
superheat *n*	перегрев
pump *v*	подавать насосом
recondence *v*	повторно конденсироваться
void coefficient of reactivity	паровой (пустотный) коэффициент реактивности

1. Read and translate Text IIA.

Text IIA. Pressurized Water Reactor

A number of reactor technologies have been developed. Fission reactors can be divided roughly into classes, depending on the energy of the neutrons that are used to sustain the fission chain reaction. There are a lot of different types of nuclear reactors. Current families of reactors are: Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR), Fast Breeder Reactor (FBR), Pressurized Heavy Water Reactors (PHWR or CANDU), Advanced Gas-Cooled Reactors (AGR), Light Water Graphite-Moderated Reactor (RBMK), Research Reactors, etc.

Let's discuss one of them, the Pressurized Water Reactor.

Pressurized Water Reactors (PWRs) also (VVER if of Russian design) are generation II nuclear power reactors that use ordinary (light) water under pressure (superheated water) as a coolant and neutron moderator in the state of high temperature and high pressure not boiling in the reactor core (primary system: reactor coolant system) and sends the high-temperature and high-pressure water to steam generators (primary system) to generate steam with heat exchangers (steam system: secondary coolant system) for a turbine generator to generate electricity.

The PWR consists of a primary system (reactor system) and a secondary system (steam system) in order to keep radioactive materials in the primary system. The reactor coolant in a reactor vessel of the primary system is pressurized so that it circulates with reactor coolant pumps without boiling, and the high-temperature and high-pressure reactor coolant (reactor-vessel outlet temperature: about 325 °C, reactor-vessel inlet pressure: about 157 kg/cm^2, at rated power) moves from a reactor core to steam generators for effective heat transfer. With the steam generators, heat exchange occurs at heat transfer tubes transporting the heat from the primary side to the secondary side, and steam is generated. This steam is sent to a turbine to drive a generator, condensed in condensers to water, and sent back to the steam generators (secondary side) with main feedwater pumps).

A PWR design includes such systems as: the primary cooling system, chemical and volume control system, emergency core cooling system, container spray system, residual heat removal system, fuel handling system, waste processing system, turbine-generator system, etc.

The primary coolant loop is kept under high pressure to prevent the water from reaching film boiling, hence the name. PWRs are the most common type of power producing reactor and are widely used all over the world.

A PWR works because the nuclear fuel in the reactor vessel is engaged in a chain reaction, which produces heat, heating the water in the primary coolant loop by thermal conduction through the fuel cladding. The hot water is pumped into a heat exchanger called steam generator, which allows the primary coolant to heat up and boil the secondary coolant. The transfer of heat is accomplished without mixing the two fluids. This is desirable, since the primary coolant is necessarily radioactive. The steam formed in the steam generator is allowed to flow through a steam turbine, and the energy extracted by the turbine is used to drive an electric generator.

In a nuclear power station, the steam is fed through a steam turbine which drives a generator connected to the electric grid for distribution. After passing through the turbine the secondary coolant (water-steam mixture) is cooled down and condensed in a condenser before being fed into the steam generator again. This converts the steam to a liquid so that it can be pumped back into the high pressure steam generator.

Two things are characteristics for the pressurized water reactors (PWR) when compared with other reactor types:

• In a PWR, there are two separate coolant loops (primary and secondary), which are both filled with ordinary water.

• The pressure in the primary coolant loop is typically 15 – 16 Megapascal, which is notably higher than in other nuclear reactors, and nearly twice that of a Boiling water reactor (BWR). As an effect of this, only localized boiling occurs and will recondense promptly in the bulk fluid.

Coolant

Water is used as primary coolant in a PWR and flows through the reactor at a temperature of roughly 315 °C (600 °F). The water remains liquid despite the high temperature due to the high pressure in the primary coolant loop (usually 15 atm, 2200 psig). The primary coolant loop is used to heat water in a secondary circuit that becomes saturated steam — in most designs 6.2 MPa (60 atm, 900 psia), 275 °C (530 °F) — for use in the steam turbine.

Moderator

Pressurized water reactors, like thermal reactor designs, require the fast fission neutrons in the reactor to be slowed down (a process called moderation) in order to sustain its chain reaction. In PWRs the coolant water is used as a moderator by letting the neutrons undergo multiple collisions with light hydrogen atoms in the water, losing speed in the process. This "moderating" of neutrons will happen more often when the water is more dense (more collisions will occur). The use of water as a moderator is an important safety feature of PWRs, as any increase in temperature causes the water to expand and become less dense; thereby reducing the extent to which neutrons are slowed down and hence reducing the reactivity in the reactor. Therefore, if reactivity increases beyond normal, the reduced moderation of neutrons will cause the chain reaction to slow down, producing less heat. This property, known as the negative temperature coefficient of reactivity, makes PWR reactors very stable.

In contrast, The RBMK reactor design applied in Chernobyl, which uses graphite instead of water as a moderator and uses boiling water as a coolant, has positive coefficient of reactivity, that increases heat generation when coolant water temperatures increase. This makes the RBMK design less stable than pressurized water reactors. In addition to its property of slowing down neutrons when serving as a moderator, water also has a property of absorbing neutrons, albeit to a less degree. When the coolant water temperature increases, the boiling increases, which creates voids. Thus there is less water to absorb thermal neutrons that have already been slowed down by the graphite moderator, causing an increase in reactivity. This property is called the void coefficient of reactivity, and in a RBMK reactor, the void coefficient is positive. This design characteristic of the RBMK reactor is generally seen as one of the several causes of the Chernobyl accident.

2. Answer the questions.

1. What types of nuclear reactors do you know?
2. Why is the PWR the most common type of power producing reactors?
3. What systems does the PWR reactor design include?
4. What substance is used as a primary coolant and as a moderator in a PWR?
5. For what purposes is the primary coolant loop used to?
6. What coefficient increases heat generation when coolant water temperature increases?
7. What makes the RBMK design less stable than PWRs?
8. What other property does water have?

3. Describe the PWR design and operation.

4. Look through Text IIA and write down the attributive constructions consisting of two-three-four or more components. Translate them into Russian.

5. Fill in the appropriate question tag.

1. Nuclear energy can be considered as an alternative to fossil fuel, ____________ ?

2. Nuclear fuel is any material that can be consumed to derive nuclear energy ____________ ?

3. Some commercial reactors with a high neutron economy do not require the fuel to be enriched at all, ____________?

4. The “moderating” of neutrons will happen more often when the water is more dense, ____________?

5. Scientists have succeeded in breaking apart the nuclei of billions of atoms and in harnessing their energy, ____________?

6. In a sustained nuclear chain reaction, the fission of a single fuel nuclear releases a few neutrons, ____________?

7. Control rods normally require sophisticated monitoring equipment, ____________?

8. The management of waste produced by the nuclear industry was not originally a sizable preoccupation ____________?

6. Translate the sentences paying attention to Participle I, II.

1. He referred to experimental results while explaining the phenomenon in terms of multiple reflections.
2. Allowing for these changes, we may predict time behavior.
3. The methods of measurements developed lately differ greatly from the old ones.
4. The successful results of the experiments received at this laboratory are very important for the new technological process being developed.
5. While making the experiment we made use of all data available.
6. Having been used for a long time, the device partly lost its efficiency.
7. Having been well tested, the nuclear reactor of new generation was put into operation.
8. Having studied the problem Franklin came to the conclusion that electricity is a kind of immaterial fluid existing in all bodies.

7. Choose the appropriate word from the bracket to join the sentence.

1. PWR reactors are very stable (**due to** / **because**) their tendency to produce (**less / more**) power as temperature increases.
2. It (**significantly / extremely**) reduces the chance that the reactor will run out of control.
3. It is possible to build a fast neutron reactor (**in addition / because**) water acts as a neutron moderator.
4. Water reactor may (**however** / **moreover**) achieve breeding ratio greater than unity, (**furthermore** / **though**) these have advantages of their own.
5. A sudden cooling of the reactor coolant could increase power production (**because** / **because of**) the reactor produces energy more (**quickly** / **slowly**) at higher temperatures.
6. The pressurized water reactor has to go off-line for (**definitely** / **comparably**) long periods of time.

8. Translate the sentences from Russian into English.

1. Реакторы с водой под давлением относятся к реакторам второго поколения, использующим перегретую воду (воду под давлением) в качестве теплоносителя.
2. Это свойство, известное как отрицательный температурный коэффициент реактивности, делает реакторы PWR довольно стабильными.
3. Если реактивность превышает нормальный уровень, сниженное замедление нейтронов вызовет ослабление цепной реакции, производя меньше теплоты.
4. Регулирующие стержни позволяют регулировать скорость реакции и, следовательно, выход тепла путем поглощения некоторых движущихся нейтронов.
5. В реакторе типа PWR тепло отводится из реактора водой, протекающей по замкнутому контуру высокого давления.

6. Когда регулирующие стержни выводятся из активной зоны, образуется больше нейтронов и цепная реакция ускоряется, производя больше теплоты.

7. Когда регулирующие стержни вводятся в активную зону, больше нейтронов поглощается, и цепная реакция замедляется или останавливается, снижая выделение теплоты.

8. Большинство промышленных ядерных реакторов используют обычную воду для отвода тепла, получаемого в результате процесса деления.

9. Read and translate Text IIB.

Text IIB. PWR Reactor Advantages and Disadvantages

Reactor Control

Generally, reactor power can be viewed as following steam (turbine) demand due to the reactivity feedback of the temperature change caused by increased or decreased steam flow. Boron and control rods are used to maintain primary system temperature at the desired point. In order to decrease power, the operator throttles shut turbine inlet valves. This would result in less steam being drawn from the steam generators. This results in the primary loop increasing in temperature. The higher temperature causes the reactor to fission less and decrease in power. The operator could then add boric acid and / or insert control rods to decrease temperature to the desired point.

Reactivity adjustments to maintain 100 % power as the fuel is burned up in most commercial PWRs is normally controlled by varying the concentration of boric acid dissolved in the primary reactor coolant. The boron readily absorbs neutrons and increasing or decreasing its concentration in the reactor coolant will therefore affect the neutron activity correspondingly. An entire control system involving high pressure pumps is required to remove water from the high pressure primary loop and re-inject the water back in with differing concentrations of boric acid. The reactor control rods, inserted through the top directly into the fuel bundles, are moved for the following reasons.

1. To enable reactor start up.
2. To shut down the reactor
3. To compensate for nuclear poison inventory.
4. To compensate for nuclear fuel depletion.

Advantages

• PWR reactors are very stable due to their tendency to produce less power as temperature increases, this makes the reactor easier to operate from a stability standpoint.

• PWR reactors can be operated with a core containing less fissile material than is required for them to go prompt critical. This significantly reduces the chance that the reactor will run out of control and makes PWR designs relatively safe from criticality accidents.

• Because PWR reactors use enriched uranium as fuel they can use ordinary water as a moderator rather than the much more expensive heavy water as in a pressurized heavy water reactor.

• PWR turbine cycle loop is separate from the primary loop, so the water in the secondary loop is not contaminated by radioactive materials.

Disadvantages

• The coolant water must be highly pressurized to remain liquid at high temperatures. This requires high strength piping and a heavy pressure vessel and hence increases construction costs. The higher pressure can increase the consequences of a loss of coolant accident.

• Most pressurized water reactors cannot be refueled while operating. This decreases the availability of the reactor — it has to go off-line for comparably long periods of time (some weeks).

• The high temperature water coolant with boric acid dissolved in it is corrosive to carbon steel (but not stainless steel), this can cause radioactive corrosion products to circulate in the primary coolant loop. This is not only limits the lifetime of the reactor, but the systems that filter out the corrosion products and adjust the boric acid concentration add significantly to the overall cost of the reactor and radiation exposure.

• Water absorbs neutrons making it necessary to enrich the uranium fuel, which increases the costs of fuel production. If heavy water is used it is possible to operate the reactor with natural uranium, but the production of heavy water requires large amounts of energy and is hence expensive.

• Because water acts as a neutron moderator it is possible to build a fast neutron reactor with a PWR design. A reduced moderation water reactor may however achieve breeding ratio greater than unity, though these have disadvantages of their own.

• Because the reactor produces energy more slowly at higher temperatures, a sudden cooling of the reactor coolant could increase power production until safety systems down the reactor.

10. Discuss the advantages and disadvantages of PWR reactors. Express your opinion using the following words and phrases from the box.

Firstly, to begin with, one advantage/disadvantage of, secondly, moreover, however, besides, on the other hand, in spite of, as opposed to the above mentioned ideas, in my opinion, in conclusion, etc.

11. Read and translate Text IIC.

Text IIC. Research Reactors

Research reactors comprise a wide range of civil and commercial nuclear reactors which are generally not used for power generation. The primary purpose of research reactors is to provide a neutron source for research other purposes. Their output (neutron beams) can have different characteristics depending on use. There are small relative to power reactors whose primary function is to produce heat to make electricity. Their power is designated in megawatts (or kilowatts) thermal (MWth or MWt), but here we will use simply MW (or kW). Most range up to 100MW, compare with 3000 Mw for a typical power reactor. In fact, the total power of the world's 283 research reactors is little over 3000 MW.

Many of the world's nuclear research reactors are used for research and training, materials testing, or the production of radioisotopes for medicine and industry. They are basically neutron factories. There are about 280 such reactors operating in 56 countries. Some operate with high-enriched uranium fuel, and international efforts are underway to substitute low-enriched fuel.

Research reactors are simpler than power reactors and operate at lower temperatures. The need far less fuel, and far less fission products build up as the fuel is used. On the other hand, their fuel requires more highly enriched uranium, typically up to 20 % U-235, although some older ones use 93 % U-235. They also have a very high power density in the core, which requires special design features. Like power reactors, the core needs cooling, and usually a moderator is required to slow down the neutrons and enhance fission. As neutron production is their main function, most research reactors also need a reflector to reduce neutron loss from the core.

A common design (67 units) is the pool type reactor, where the core is a cluster of fuel elements sitting in a large pool of water. Among the fuel elements are control rods and empty channels for experimental materials. Each element comprises several (e. g. 18) curved aluminium-clad fuel plates in a vertical box. The water both moderates and cools the reactor, and graphite or beryllium is generally used for the reflector, although other materials may also be used. Apertures to access the neutron beams are set in the wall of the pool.

Research reactors have a very wide variety of uses, including neutron scattering (in which beams of thermal neutrons are scattered by the atoms in a sample, revealing its structure, magnetic state, and atomic binding energies); neutron activation analysis, radiography, irradiation testing of materials, and production of radioisotopes for medical, research, and industrial use. These capabilities are applied by researchers in many fields, ranging from archeology to materials science and from fusion research to environmental science. There are few generalizations to be made about the applications for research reactors or about their users.

12. Speak about the specific feature of this reactor type operation.

13. Compare this reactor type with the PWR one.

14. Give a summary of this text in written form.

PROGRESS TEST 2

Task 2. Complete the sentences with the words from the box and translate the text from English into Russian without a dictionary.

Fissile uranium, fuel bundles, enrichment, fuel rods, safety measures, heat conduction, refueling, ceramic pellets, prompt criticality.

Text 2. Reactor Fuel

The uranium used in PWR reactor as a fuel is usually enriched several percent in U-235. After __________ the uranium dioxide powder is fired in a high-temperature, sintering furnace to create hard, __________ of enriched uranium dioxide. The cylindrical pellets are then pt into tubes of a corrosion-resistant zirconium metal alloy which are backfilled with helium to aid __________ and detect leakages. The finished fuel rods are grouped in fuel assemblies, called __________, that are then used to build the core of the reactor. As a __________ PWR designs do not contain enough __________ to sustain a prompt critical chain reaction. Avoiding __________ is important as a prompt critical chain reaction could very rapidly produce enough energy to damage or even melt the reactor. A typical PWR has fuel assemblies of 200-300 rods each. Generally, the __________ consist of fuel rods bundled 14 × 14 to 17 × 17. A PWR produces on the order of 900 to 1,500 MWe. __________ for most PWRs is on an 18 – 24 month cycle. Approximately one third of the core is replaced each refueling.

UNIT III

New Words and Word Combinations

ceramic pellet	керамическая таблетка
fission fragments	осколки деления
half-life *n*	период полураспада
handle *v*	обращаться, обрабатывать
heat release	тепловой выброс
heat removal	отвод (съем) теплоты
high level waste	высокоактивные отходы
interim storage	промежуточное хранение
neutron capture	захват нейтрона
repository *n*	хранилище (радиоактивных отходов)
remove *v*	удалять, отводить
site *n*	рабочая площадка
split *n*	расщепление
storage facility	оборудование для хранения
supervised pool	контролируемый бассейн
trapped *adj*	захваченный
waste disposal	удаление (захоронение) радиоактивных отходов
waste management	управление радиоактивными отходами

1. Read and translate Text IIIA using a dictionary.

Text IIIA. Waste from Nuclear Power

The generation of electricity in a Nuclear Power Plant is made by splitting uranium atoms. The uranium used as fuel in a nuclear plant is formed into ceramic pellets about the size of the tip of your little finger. The uranium atoms in these pellets are bombarded by atomic particles, they split (or fission) to release particles of their own. These particles, called neutrons, strike other uranium atoms, splitting them. When the atoms split, they also release heat. This heat is known as nuclear energy and is essentially responsible for creating electricity. Other reactions also take place in the nuclear reactor such as neutron capture. Neutron capture is a term used for the scenario where a neutron comes close to a nucleus and the nucleus captures it and becomes a different nucleus. In this case when uranium-238 captures a neutron it becomes uranium-239. After uranium-239 emits a beta particle (electron) it becomes neptunium-239. Then neptunium-239 also emits a beta particle and becomes plutonium-239. The plutonium can also be used as nuclear fuel.

Certain changes take place in the ceramic fuel pellets during their time in the reactor of the nuclear power plant. The particles left over after the atom has split are radioactive. During the life of the fuel, these radioactive particles collect within the fuel pellets. The fuel remains in the reactor until trapped fission fragments begin to reduce the efficiency of the chain reaction. Some of the fission products are various isotopes of barium, strontium, cesium, and iodine. The spent fuel also contains plutonium and uranium that was not used up. The fission products and the left over plutonium and uranium remain within the spent fuel when it is removed from the reactor and are called high level waste as they are extremely hot and very radioactive.

Since the spent nuclear reactor (SNF) fuel is highly radioactive initially it is too dangerous to handle and thus it is very important to shield the radioactivity from humans and the environment. The radioactive material in the SNF generally falls into three categories: (1) un-reacted fuel, usually uranium, (2) fission products, and (3) activation products, most notably plutonium. Because of the nature of radioactivity, on a per-atom or by weight basis the fission products are by far the most radioactive, and have the shortest half-life. The un-reacted uranium and the plutonium have vastly longer half-lives, but are correspondingly less radioactive. Once the SNF has been removed from the nuclear reactor it is placed in interim storage at the reactor site. Usually this consists of putting the nuclear waste into large pools of water. The water cools the radioactive isotopes and shields the environment from the radiation. Nuclear waste is typically stored in these supervised pools between 20–40 years. As the SNF ages the radioactivity decreases, reaching the point where it does not need to be water cooled and can be placed in dry storage facilities. Throughout this time there is a great reduction in heat and radioactivity and this makes handling of nuclear waste safer and easier.

After this "cooling off" period the high level waste can be handled in different ways. It can be reprocessed then disposed of permanently or directly disposed permanently in a geological repository.

2. Answer the questions.

1. What is electricity generation made by?
2. What is uranium atoms formed into?
3. What reactions take place to create electricity?
4. When do the radioactive particles collect within the fuel pellets?
5. What substances does the spent fuel contain?
6. What is called high level wastes?
7. Why is it dangerous to handle the spent fuel?
8. Where is the spent nuclear fuel placed after removal from the nuclear reactor?

3. Speak about the categories of spent nuclear fuel.

4. Put the verbs in brackets into the correct form or the -ing form.

1. The generation of electricity in NPP is made by … (split) uranium atoms.
2. The uranium … (use) as fuel in a nuclear plant is formed into ceramic pellets.
3. The heat known as nuclear energy is responsible for … (create) electricity.

4. Fuel … (remain) in the reactor until … (trap) fission fragments begin … (reduce) the efficiency of the chain reaction.

5. This makes ….(handle) of nuclear waste safer and easier.

6. The cost of … (manage) and (dispose) of radioactive wastes is part of the electricity cost.

5. Fill in the gaps using the words from the list below.

After, since, because of, typically, highly, during, essentially

1. The heat is known as a nuclear energy and is … responsible for creating electricity.

2. … the nature of radioactivity, the fission products are by far the most radioactive, and have the shortest half-life.

3. … the spent fuel reactor fuel is radioactive initially it is too dangerous to handle it.

4. Nuclear waste is … stored in these supervised pools between 20 – 40 years.

5. … this "cooling off" period the high level waste can be handled in different ways.

6 …. the life of the fuel, these radioactive particles collect within the fuel pellets.

6. Translate the following word combinations from Russian into English.

Ядерная энергия, расщепление атомов урана, захват нейтрона, керамические топливные таблетки, осколки деления, испускать бета частицы, цепная реакция, отработавшее топливо, высокорадиоактивные отходы, самый короткий период полураспада, обработка радиоактивных отходов, отвод тепла.

7. Make up 3 – 4 sentences using the word combinations above.

8. Translate the sentences paying attention to the Degrees of Comparison.

1. The un-reacted uranium and plutonium have vastly longer half-lives and are correspondingly less radioactive.
2. Hence, the higher the intensity of radioactivity in a given amount of materials, the shorter the half lives involved.
3. In addition, the smaller the core and the lower coolant density reduce the volume of water that must be held within the containment vessel in the event of an accident.
4. The adiabatic heat up rate is at least much higher in the research reactors.
5. Most of operating facilities in the U.S. have much lower power levels, with even greater differences from the power reactors.
6. Eventually all radioactive wastes decay into non-radioactive elements. The more radioactive an isotope is, the faster it decays.

9. Translate the sentences into Russian paying attention to the translation of the conjunction *since*.

1. **Since** the distance of the electrons from the nucleus is about a hundred thousands times as large as the diameter of the nucleus, most of the atom consist of empty space.
2. Zircaloy control rod guide tubes exhibit axial growth to a lesser extent than the cladding tubes **since** the material in the guide tubes is used in the fully recrystallized condition.
3. Zircaloy corrosion is nowadays considered to be the potentially most important limitation on design burnup in modern high-efficiency PWRs, **since** the rate of corrosion strongly depends on the temperature.
4. The total fuel rod defect rate **since** 1977 amounts to 3.2×10^{-5} per cycle on average.

5. However, **since** the reactor fuel mostly consists of uranium, it represents a potentially valuable resource and there is an increasing reluctance to dispose of it irretrievably.

6. Today, there has been no practical need for final high-level radioactive waste repositories, **since** surface storage for 40–50 years is first required so that heat and radioactivity can decay to levels which make handling and storage easier.

7. **Since** nuclear power plants are fundamentally thermal energies, waste heat disposal becomes an issue at high ambient temperature.

10. Translate the sentences from Russian into English:

1. Захоронение радиоактивных отходов является основной проблемой ядерной энергетики.
2. Радиоактивные выбросы в окружающую среду начинаются с добычи урана.
3. Радиоактивные отходы производятся на каждой ступени ядерного топливного цикла.
4. Уран — топливо, которое не выделяет диоксид углерода.
5. Радиоактивные отходы подразделяются на три типа: малоактивные, среднеактивные и высокоактивные отходы.
6. Высокоактивные отходы вырабатывают теплоту и должны постоянно охлаждаться.
7. Захоронение радиоактивных отходов вызывает общественное беспокойство.
8. Радиоактивные выбросы неблагоприятно воздействует на окружающую среду.

11. Read and translate Text III B using a dictionary.

Text IIIB. Radioactive Waste Management

Like all industries, the thermal generation of electricity produces wastes. Whatever fuel is used, these wastes must be managed in ways which safeguard human health and minimize their impact on the environment.

Nuclear power is the only large-scale energy-producing technology which takes full responsibility for all its wastes and fully costs this into product. The amount of radioactive wastes is very small relative to wastes produced by fossil fuel electricity generation. Used nuclear fuel may be treated as a resource or simply as a waste. Safe methods for the final disposal of high-level radioactive waste are technically proven: the international consensus is that this should be deep geological disposal.

All parts of the nuclear fuel cycle produce some radioactive wastes (radwaste) and the cost of managing and disposing of this is part of the electricity cost, i.e. it is internalized and paid for by the electricity consumers.

Radioactive wastes comprise a variety of materials requiring different types of management to protect people and the environment. They are normally classified as low-level, medium-level or high-level wastes, according to the amount and types of radioactivity in them.

Another factor in managing wastes is that they are likely to remain hazardous. This depends on the kinds of radioactive isotopes in them, and particularly the half lives characteristic of each of those isotopes. The half life is the time it takes for a given radioactive isotope to lose half of its radioactivity. After four half lives the level of radioactivity is $1/16^{th}$ of the original and after eight half lives $1/256^{th}$. The various radioactive isotopes have half lives ranging from fractions of a second to minutes, hours or days, through to billions of years. Radioactivity decreases with time as these isotopes decay into stable, non-radioactive ones. The rate of decay of an isotope is inversely proportional to its half life; a short half life means that it decays rapidly. Hence, for each kind of radiation, the higher the intensity of radioactivity in a given amount of material, the shorter the half lives involved.

There are three general principles to be employed in the management of radioactive wastes:

• concentrate-and-contain;
• dilute-and-disperse;
• delay-and-decay.

The first two are also used in management of non-radioactive wastes. The waste is either concentrated and then isolated, or it is diluted to acceptable levels and then discharged to the environment. Delay-and-decay however is unique to radioactive waste management; it means that the waste is stored and its radioactivity is allowed to decrease naturally through decay of the radioisotopes in it.

Radioactive wastes occur at all stages of the nuclear fuel cycle — the process of producing electricity from nuclear materials. The fuel cycle comprises the mining and milling of the uranium ore, its processing and fabrication into nuclear fuel, its use in the reactor, the treatment of the used fuel taken from the reactor after use and finally, disposal of the wastes. The fuel cycle is often considered as two parts — the "front end" which covers the removal of used fuel from the reactor and its subsequent treatment and disposal. This is where radioactive wastes are a major issue.

12. Speak about three general principles of management of radioactive wastes.

13. Read and translate Text IIIC.

Text IIIC. Nuclear Waste Storage and Disposal

The major problem of nuclear waste is what to do with it. In fact, one of the biggest expenses of the nuclear power industry could eventually be the storage of nuclear waste. Currently there are several ways in which nuclear waste is stored. Most of these methods are temporary. In most cases a viable long-term storage is so incredibly long, on the order of thousands of years.

The spent fuel rods are removed from the reactor core, they are extremely hot and must be cooled down. Most nuclear power plants have a temporary storage pool next to the reactor. The spent rods are placed in the pool, where they can cool down. The pool is not filled with ordinary water but with boric acid, which helps to absorb some of the radiation given off by the radioactive nuclei inside the spent rods. The spent fuel rods are supposed to stay in the pool for only about 6 months, but because there is no permanent storage site, they often stay there for years. As pools fill, there are major problems. If the rods are placed too close together, the remaining nuclear fuel could go critical, starting a nuclear chain reaction. Thus, the rods must be monitored and it is very important that the pools do not become too crowded. Also, as an additional safety measure, neutron-absorbing materials similar to those used in control rods are placed amongst the fuel rods. Permanent disposal of the spent fuel is becoming more important as the pools become more and more crowded.

Another method of temporary storage is now used because of the overcrowding of pools. This is called dry storage. Basically, this entails taking the waste and putting it in reinforced casks or entombing it in concrete bunkers. This is after the waste has already spent about 5 years cooling in a pool. The casks are also usually located close to the reactor site.

There are many ideas about what to do with nuclear waste. The low-level (not extremely radioactive) waste can often be buried near the surface of the earth. It is not very dangerous and usually will have lost most of its radioactivity in a couple hundred years.

The high-level waste, comprised mostly of spent fuel rods, is harder to get rid of. There are still plans for its disposal, however. Some of these include burying the waste under the ocean floor, storing it underground, and shooting it into space. The most promising option so far is burying the waste in the ground. This is called "deep geological disposal". Because spent fuel rod contains material that takes thousands of years to become stable (and non-radioactive), it must be contained for a very long time. If it is not contained, it could come in contact with human population centers and wildlife, posing a great danger to them. Therefore, the waste must be sealed up tightly. Also, if the waste is being stored underground, it must be stored in an area where there is little groundwater flowing through. If ground water does flow through a waste storage site, it could erode the containment canisters and carry waste away into the environment. Additionally, a disposal site must be found with little geological activity. The waste will probably be encapsulated in a large casks designed to withstand corrosion, impact, radiation, and temperature extremes. Special casks will also have to be used to transfer fuel rods from their holding pools and dry storage areas next to the reactor to the permanent geological storage site.

14. Make a round-table talk discussing the major problem of nuclear wastes.

PROGRESS TEST 3

Task 3. Complete the sentences with the words from the box and translate the text from English into Russian without a dictionary.

Reactor core, safety measure, nuclear wastes, storage pool, spent fuel rods, site, chain reaction, boric acid, permanent disposal, radioactive nuclei.

Text 3. Temporary Storage of Fuel Rods

The spent fuel rods from a nuclear reactor are the most radioactive of all ____________. When all the radiation given off by nuclear waste is tallied, the fuel rods give off 99% of it, in spite of having relatively small volume. There is no permanent storage site of ____________. Temporary storage is being used while a permanent site is searched for and prepared.

When the spent fuel rods are removed from the ____________, they are extremely hot and must be cooled down. Most nuclear power plants have a temporary ____________ next to the reactor. The spent fuel rods are placed in the pool, where they can cool down. The pool is not filled with ordinary water but with ____________, which helps to absorb some of the radiation given off by the ____________ inside the spent rods. The spent fuel rods are supposed to stay in the pool for only about 6 months, but, because there is no permanent storage ____________, they often stay there for years. As pool fills, there are major problems. If the rods are placed too close together, the remaining nuclear fuel could go critical, starting a nuclear ____________. Thus, the rods must be monitored and it is very important that the pools do not become too crowded. Also, as an additional ____________, neutron-absorbing materials similar to those used in control rods are placed amongst the fuel rods. ____________ of the spent fuel is becoming more important as the pools become more and more crowded.

UNIT IV

New Words and Word Combinations

accident *n*	авария, поломка, повреждение
attribute *n*	свойство
concrete *n*	бетон
contribute *v*	способствовать, делать вклад
controversial *adj*	спорный
disposal *n*	захоронение (радиоактивных отходов)
employeer *n*	служащий
greenhouse effect	парниковый эффект
harm *v*	вредить, повреждать
operating nuclear power unit	действующий атомный энергоблок
precautions *n* (*pl*)	меры предосторожности
process wastes	обрабатывать отходы
pros and cons	доводы «за» и «против»
radiation build-up	радиоактивные накопления
radiation spill	радиационная утечка
recycled fuel	повторно используемое топливо
safety-in-depth *n*	защита в глубину

1. Read and translate Text IVA.

Text IVA. The Pros and Cons of Nuclear Energy

Nuclear power is the controlled use of nuclear reactions to release energy and heat. Energy is released from the nuclei of atoms when they split, fuse or release radiation.

Nuclear energy is a very controversial source of fuel. Some people believe the nuclear waste created, though minimal, is harming our environment. Others support it because of the lavish amounts of electricity it produces. Currently there are one hundred four operating nuclear power units in our country. This supplies us with up to twenty percent of our nation's energy. Nuclear energy has many good attributes. First of all, nuclear energy is nature-friendly. Fossil fuel burning releases as much as 5.6 billion tons of carbon dioxide into the air each week, which contributes to the greenhouse effect. Electricity made by a nuclear plant does not. Also, the nuclear reactors are built with a series of layers of defense made to protect the environment from radiation spills. This is called "safety-in-depth".

Nuclear reactors are made with sensors that watch temperature, pressure, and water levels. The sensors are designed to shut down the system at any sign of danger. Also, the buildings are made of steel and have four feet thick concrete walls. Employees of a nuclear plant receive many hours of training in case of an emergency.

Nuclear energy also contributes to our world's growing need for energy. Fossil fuels take million of years to develop and we may soon run out of it. Plus, pollution caused by burning fossil fuels is destroying the ozone and is adding on to the greenhouse effect. Coal fired plants let out coal smoke, which is filled with sulfur dioxide and causes acid rain that destroys forests and lakes.

Nuclear energy produces small amounts of wastes that is processed and disposed of. Nuclear fuel is a type of waste, and twenty-eight tons of it is produced every year. Most nuclear waste is recycled and reused. Uranium and pollution are two examples; uranium is made into new fuel pellets and sent back to the reactors and plutonium is mixed in with the uranium. Nuclear energy has become one of the most economic, cheap, and reliable sources of energy for everyone.

Nowadays, nuclear reactors are built with special programs to prevent explosions or the release of harmful radiation into the environment. Sometimes, though, accidents happen. This is a big reason why the construction of more nuclear plants has been questioned. An example would be the accident in Chernobyl, Ukraine on April 26, 1986 when a nuclear reactor exploded and high levels of radiation were spread out through the surrounding land. After that accident, scientists and engineers have taken more precautions and have built more safety measures to prevent anything like that from happening again.

Another growing concern with using nuclear energy is the cost. Already, over $300 billion dollars have been invested into the energy.

A big problem for disposal spent fuel and used uranium has arisen. Nuclear planners came up with the idea of burying it deep underground, and the mountain has been the only suitable place so far. A Nevada State Agency said that in 10 years, the radiation build-up would kill anybody in a three-feet radius of it in less than three minutes.

Though nuclear energy does not emit carbon dioxide into the air, it does release one chemical that is very harmful to the ozone-CFC-114.

Nevertheless, nuclear energy is a very economical and reliable source of energy, especially with the growing demand for it. Nuclear energy is a great alternative to burning fossil fuels and does not pollute. Building more nuclear reactors, though costly, will be an asset to everyone.

2. Answer the following questions.

1. Why is nuclear energy a very controversial source of fuel?
2. Why do some people believe that nuclear waste is harming our environment?
3. What good attributes does nuclear energy have? Prove it.
4. What is the concept “safety-in-depth” used for?
5. What does nuclear energy produce?
6. What has influenced on people opinion concerning the usage of nuclear energy?
7. Why is spent fuel disposal a big problem?

3. Find English equivalents of the following Russian word combinations.

Загрязнения, вызванные сжиганием топлива; действующие ядерные энергоблоки; ядерная энергия не наносит вред природе; в случае аварии; ядерные отходы обрабатывают и подвергают захоронению; предотвратить взрыв и выброс вредного излучения в окружающую среду; концепция «защита в глубину», надежный источник энергии; создать меры по обеспечению безопасности.

Reliable sources of energy; nuclear energy is nature-friendly; pollution caused by burning fossil fuel; operating power units; to build safety measures; in case of emergency; to prevent explosions or release of harmful radiation into the environment; nuclear wastes are processed and disposed of; "safety-in-depth" concept.

4. Discuss in pairs the different opinion of people concerning the use of nuclear energy.

5. Complete the sentences using information from Text IVA.

1. Nuclear power is the controlled use of …
2. Nuclear energy also contributes to …
3. Nuclear energy produces small amounts of …
4. Most nuclear waste is …
5. Nuclear energy has become one of the most …
6. Nuclear reactors are built to prevent …
7. Nuclear energy is a great alternative to …

6. Translate the sentences paying attention to Subjunctive Mood.

1. It is highly desirable that physicists should solve the problem of control of dangerous radiations before we could widely use nuclear energy.

2. It is required that all nuclear reactors be environmentally-friendly.

3. Any increase in the number of fossil-fired power plants would have a catastrophic impact on our environment.

4. If reactivity increased beyond normal the reduced moderation of neutrons would cause the chain reaction to slow down.

5. The application of nuclear power to rocket propulsion would appear to provide the means of obtaining extremely high values of specific thrust. .

6 .Heat would be absorbed until the temperature of the absorbing body attains that of the heat.

7. It is necessary that fuel lines should be protected against heat.

8. If there were less water to absorb thermal neutrons it would cause an increase in reactivity.

7. Read and translate Text IVB.

Text IVB. Six Reasons Against Nuclear Energy

Europe does not need nuclear power. As various scenarios show, Europe's future energy needs can be met from other sources while still drastically reducing greenhouse gas emissions in order to limit climate change. Europe needs massive investments in renewable energies as well as in cutting back energy waste through increasing efficiency. The technology is available & affordable — and creates many more jobs than any nuclear power scenario.

1. Nuclear power is dangerous, safety is a myth

Nuclear power remains the most dangerous form of energy. A disaster like the Chernobyl accident, now 20 years ago, can happen anytime anyplace. The history of the Nuclear Age is a history of accidents. 20 years after Chernobyl, people are still suffering from health problems caused by the accident. An accident can occur at any nuclear reactor, causing the release of large quantities of radioactivity into the environment. Even during normal operation, radioactive materials are regularly discharged into the air and water. Transports of large quantities of low and intermediate level wastes are also increasing the risks to populations.

Although nuclear power is a hazardous business, the nuclear industry hardly has any financial liability. In the case of nuclear disaster, most of the damages will be paid by society and not the companies' insurances. None of the various international conventions on nuclear damage currently in force are designed to make operators, or owners, of nuclear facilities liable for damage they cause.

2. Nuclear power is a deadly legacy for our children

A solution for the long-term storage & treatment of radioactive waste has yet to be found. Highly radioactive spent fuels need to be isolated from the biosphere for hundreds and thousands years. Nuclear waste is produced at every stage of the nuclear fuel cycle, from uranium mining and reactors to the reprocessing of spent nuclear fuel. Radioactive waste remains dangerous for hundreds and thousands of years and radiation can lead to cancer and birth defects.

There is not a single safe disposal option for the highly radioactive waste produced by nuclear power stations worldwide. In almost all countries waste is stored in bunkers, below surface or above ground, while the world desperately researches ways to safely store it for thousands of years to come. These "intermediate" storages are expensive and require safety measures that are not comparable to any other waste or industrial process. As there is no safe way to store these wastes for the necessary periods of time, this alone should be enough reason to abandon nuclear power as a viable energy source.

3. Nuclear power is a financially insane

If the European energy market was a level playing field, where energy pricing would reflect the true costs of producing energy from different sources, nuclear power would be economically insane. All countries using its technology have seriously underestimated the full costs of nuclear power. Nuclear power will not be able to compete with renewable energies without huge amounts of state aid. That nuclear power today produces one third of Europe's electricity is due to political that creates favourable market conditions.

Most of the costs of a serious nuclear accident will be borne by society and not by the plant operator's insurance. The costs of waste disposal, decommissioning of plants at the end of their lifespan and provisioning for accidents have never been adequately accounted for, and will result in a massive burden on future economies and generations.

4. Nuclear power is no solution to climate change

In order to avoid the most catastrophic effects of global warming, the world has to cut back its emissions of heat-trapping greenhouse gases by around 50% by 2050. Since by far the most of emissions happen in the energy sector, the nuclear industry hopes to use the climate crisis to stage a nuclear revival, arguing that nuclear power is cheap, emission-free and thus has a role to play in securing low-emissions supply of energy.

But nuclear power is not at all emissions free, if emissions in relation to uranium mining, transportation, plant construction and decommissioning and waste storage are included in calculation. Fossil fuels are needed to run the nuclear cycle.

5. Nuclear weapons are the flip side of nuclear power

Radioactive material from nuclear power generation can be used to build nuclear weapons. The global expansion of nuclear power could contribute to an increase in the number of nuclear weapons states. So far India, Israel, South Africa, Pakistan, North Korea and of course The five official nuclear weapons states such as US, Russia, UK, France and China have developed arsenals of nuclear weapons using their “peaceful” nuclear facilities. The spread of nuclear technology significantly increases the risk of nuclear weapons proliferation. Smuggling of nuclear material, including from civil nuclear programs, also presents a significant challenge.

6. Nuclear power dependent on limited & dirty resources

Nuclear power plants run on uranium — like oil, gas and coal — is a finite resource that will only last a few more decades, at most 50 years. A significant increase in the use of nuclear power will quickly result in a shortage of nuclear fuel. The reprocessing of spent fuel has already been proven to be no solution. Reprocessing is a complicated and hazardous chemical process that creates an enormous amount of radioactive waste. Besides that, reprocessing is a very uneconomical technology. Nevertheless, there are two reprocessing units in Europe: Sellafield (UK) and La Hague (France). Both are known to be the biggest sources of radioactive pollution in the European environment through the release of huge quantities of radioactive liquid effluents into the sea and gaseous discharges into the air.

8. Make a round-table talk discussing six reasons against nuclear energy.

9. Read Text IVC.

Text IVC. Pros of Nuclear Power Generation

Whether you view nuclear power as the promise for a better tomorrow or a whopping down payment on a mutant-filled apocalypse, there’s a good chance you won’t be easily converted to the other side. After all, nuclear power boasts a number of advantages, as well as its share of downright depressing negatives.

As a result of the current discussion how further global warming could be prevented or at least mitigated, the revival of nuclear power seems to be in everybody's — or at least in many politician's — mind. It is interesting to see that in many suggestions to mitigate global warming, the focus is put on the advantages of nuclear power generation, its disadvantages are rarely mentioned.

Pros:

1. Little pollution.

As far as positives go, nuclear power's biggest advantages are tied to the simplest fact that it doesn't depend on fossil fuels. Coal and natural gas power plants emit carbon dioxide into the atmosphere, contributing to climate change. With nuclear power plants, CO_2 emissions are minimal.

As demands for electricity soars, the pollution produced from fossil fuel burning plants is heading towards dangerous levels. Coal, gas and oil burning power plants are already responsible for air pollution. Burning coal produces carbon dioxide, which depletes the protection of the ozone. The soft coal, which many power plants burn, contains sulfur. When the gaseous byproducts are absorbed in clouds, precipitation becomes sulfuric acid. Coal also contains radioactive material. A coal-fired power plant emits more radiation into the air than a nuclear power plant. In fact, a properly functioning nuclear power plant actually releases less radioactivity into the atmosphere than a coal-fired power plant. By not depending on fossil fuels, the cost of nuclear power also isn't affected by fluctuations in oil and gas prices.

The world's reserves of fossil fuels are running out. The sulfurous coal which plants use is more polluting than the coal that was previously used. Most of the anthracite, which plants also burn, has been used up. As more soft coal is used, the amount of pollution will increase. According to estimates, fossil fuels will be burned up within fifty years. There are large reserves of uranium, and now breeder reactors can produce more fuel than they use. Unfortunately, this doesn't mean we can have an endless supply of fuels (in about 1000 years), breeder reactors will cease to be useful. This is still a more lengthy solution to the current burning of coal, gas, and oil.

2. Reliability.

Nuclear power plants need little fuel, so they are less vulnerable to shortages because of strikes or natural disasters. International relations will have little effect on supply of fuel to the reactors because uranium is evenly deposited around the globe. One disadvantage of uranium mining is that it leaves the residues from chemical processing of the ore, which leads to radon exposure to the public. These effects do not outweigh the benefits by the fact that mining uranium out of the ground reduces future radon exposures. Coal burning leaves ashes that will increase future radon exposures. The estimates of radon show that it is safer to use nuclear fuel than burn coal. Mining of the fuel required to operate a nuclear plant for one year will avert a few hundred deaths, while the ashes from a coal-burning plant will cause 30 deaths.

3. Safety.

Safety is both a pro and con, depending on which way you see it. The results of a compromised reactor core can be disastrous, but the precautions that prevent this from happening prevent it well.

Nuclear power is one of the safest methods of producing energy. Each year, 10,000 to 50,000 Americans die from respiratory diseases due to the burning of coal, and 300 are killed in mining and transportation accidents. In contrast, no Americans have died or been injured because of a reactor accident or radiation exposure from American nuclear power plants. There are a number of safety mechanisms that make the chances of reactor accidents very low. A series of barriers separates the radiation and heat of the reactor core from the outside. The reactor core is contained within a 9-inch thick steel pressure vessel. The pressure vessel is surrounded by a thick concrete wall. This is inside a sealed steel containment structure, which itself is inside a steel-reinforced concrete dome four feet thick. This dome is designed to withstand extremes such as earthquakes or a direct hit by a crashing airliner. There is also a large number of sensors that is a leak. There are systems that control and stop the chain reaction if necessary. An Emergency Core Cooling System ensures that in the event of an accident there is enough cooling water to cool reactor.

10. Make up questions to find out the advantages of nuclear energy: (a) little pollution; (b) reliability; (c) safety.

11. Make up a dialogue using these questions.

12. Make a presentation proving the necessity of nuclear power generation.

PROGRESS TEST 4

Task 4. Complete the sentences with the words from the box and translate the text from English into Russian without a dictionary.

Environmental impacts, declining energy source, proponents, improved technology, radioactive contamination, sustainable energy, nuclear proliferation, energy security, nuclear power debate

Text 4. Nuclear Power Debate

The ____________ concerns the desirability of using nuclear reactors to generate electricity from nuclear fuel for civilian purposes.

____________ of nuclear energy assert that nuclear power is a compact, reliable ____________ source that reduces carbon emissions and increases ____________. Proponents highlight that nuclear energy's operational safety record is already very good when compared to other major power plant technologies. They claim that the risk of waste and other ____________. are small compared to other sources of electricity and can be further reduced by ____________. in new reactors.

Critics of nuclear energy assert that nuclear power is a potentially dangerous and ____________ and dispute that the risk can be reduced through new technology. Critics also point to the problems of storing radioactive waste, the potential for severe ____________ by accident or sabotage, the difficulty of remediating contaminated sites, the possibility of ____________. and the disadvantages of centralized electrical production.

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