1 A.E. Belayev Mechanical transmissions with provisional elements of increased longevity and accuracy. – Tomsk. TPU, 1986. – 60 p.
2 K.G. Shibinskyi, E.A. Efremenkov Classification of transmissions with provisional rolling elements// Modern problems of machine building: Researches of the IV international science-technic conference. – Tomsk, 2008. – 23-26 pp.
3 V.S. Yangulov Increased accuracy and longevity gears. – Tomsk. TPU, 2008. – 136p.
4 Transmissions with free rolling elements, review of patent literature // [electronic resource]. URL: http://www.redbear.ru/file/spo.pdf (resort day 20.02.2013).
5 R.V. Chumakin, A.V. Cheremnov, E.N. Pashkov A few about transmissions with provisional rolling elements // Researches of the XVII international science-technic conference MTT 2011. – Tomsk, part 1.
6 Geraless transmission: Pat. 3,227,005 US. Appl. No. 118,658. Fild June 21,1961. Patented Jan. 4,1966.

The Use of Thorium in Compact Reactors

Khrapov D. A.
cheshirskyvolk@mail.ru

Supervisor: Docent, PhD, Chertkov Y.B., Department of Physics and power units (PEU), PTI, TPU

Introduction

The implementation of the thorium fuel in nuclear power industry is dictated by several factors: thorium reserves in the world exceed uranium reserves in 4 - 5 times. Thorium deposits are more accessible than uranium deposits. This is especially important for Russia: explored uranium reserves in Russia will be enough only for 20 years, and there is sufficient amount of thorium resources in the fields near Novokuznetsk and Tomsk (Tugansk deposit of thorium, titanium, zirconium).

From the point of view of the use of fissile nuclides, the advantage of thorium to uranium is refractoriness of thorium: only at 1400-1500 ° C the crystal lattice of thorium begins to undergo phase transitions. This allows the reactor to operate with thorium fuel at higher temperatures. Thorium energy industry, unlike uranium, does not produce plutonium and transuranic elements. This is important both from an environmental point of view and from the point of view of non-proliferation of nuclear weapons (Selection weapon actinides out of uranium fuel allows to create a nuclear weapon for the "rogue states" and terrorists).

Only one of the thorium isotopes (Th-232) has a sufficiently long half-life with respect to the age of the earth, so virtually all of the natural thorium consists only of this nuclide. 232Th is not divided by thermal neutrons by itself, but the absorption of a neutron by thorium-232 leads to the formation of uranium-233, which has a high probability to emit neutrons by dividing the flux of thermal and intermediate neutrons. Therefore its role inside the nuclear reactor is the same as that of 238U: by absorption of neutron, they are converted into secondary thermal neutron fissionable nuclides. [1]

Thorium-232 is the best "resource" isotope in compare with uranium-238 for the reactors that works on thermal neutrons. Uranium-233 emits more than two neutrons counting on one of the captured primary neutron for a wide range of reactors with thermal neutron spectrum.

Thorium dioxide has greater chemical and radiation resistance in compare with uranium dioxide, as well as it has better thermal properties (thermal conductivity, coefficient of linear expansion). U-233 has the largest value of the coefficient η_{ef} characterizing the number of secondary neutrons per neutron absorbed in fuel - 2.29

Replacing the uranium cycle with the thorium one the rate of formation of long-lived minor actinides in nuclear reactors reduces significantly. If thorium reactor operates only in the 232U-Th cycle, the actinides with masses more than 237 will appear in the smallest quantities.

232U is the isotope, which attracts special attention in the thorium cycle . It is formed due to reactions (n, 2n) on isotopes 232Th, 233Pa and 233U. The half-life of 232U is 69 years. For example, among its daughter products there is 208Tl - an isotope with a very short lifetime emitting hard gamma-particle (2.6 MeV).

Because of accumulation of 232U doses in the thorium fuel will rise. This creates additional problems in handling with spent fuel after thorium reactor, in particular in the recycling of uranium. But at the same time the presence of 232U in burnt fuels increases security(safety) of the reactor and fuel cycle from spreading.

Additionally, thorium cycle is preferred for disposal of weapon plutonium because it does not lead to reproduction as in the case of U-Pu fuel cycle.

In thorium reactors protactinium effect will necessarily take place, it is similar to the mechanism of formation of neptunium effect in fast reactors with uranium or uranium-plutonium fuel, but more unpleasant in terms of management. In projects of thorium reactors, the rise of reactivity in extended shutdown due to the decay of 233Pa into the fissile isotope 233U must be considered.

Works on exploring the possibilities of using thorium in the nuclear fuel cycle are mainly related to the presence of large reserves of thorium (India), or with the desire to reduce the consumption of natural uranium (Norway), or the presence of nuclear energy technologies that can take advantage of the thorium fuel cycle (Canada, Russia).

India

The Government of India has given permission to start building of an experimental thorium reactor with capacity 300 MW. Stations of this type are considered to be so safe that they can be built right in the city, although experimental reactor will be built away from the city (government is choosing from two places). The reactor design of AHWR (advanced heavy water reactor) is an advanced version of the heavy-water nuclear reactor, which uses channel architecture, as well as ordinary water as a coolant. Moderator (heavy water D2O) is located in separate from the coolant channels under reduced pressure. A special feature of Indian reactor is the large water tanks that are located on top of the whole structure and function as passive safety, meaning they can cool the reactor in case of an accident.

In India, in order to increase efficiency after running in blocks 1 and 2 nuclear power plant in Kakrapare was filled with 500 kg of thorium fuel. The 1st unit was the first world reactor, wherein the alignment of power in the unused area was not depleted by uranium and thorium. Working on the thorium fuel, the 1st unit reached full capacity for 300 days and the 2nd unit - for 100 days. Thorium fuel will be used in blocks 1 and 2 in A.E.S Kaiga and in blocks 3 and 4 nuclear power plant in Rajasthan, which are being built now. With reserves of thorium that exceeds the reserves of uranium in six times, India has set the task of implementation of the thorium cycle as the primary task of the industrial production of energy, which will be addressed in three stages:

1) heavy water reactors CANDU, running on fuel from natural uranium will be used to produce plutonium;

2) a breeder reactor on fast neutrons (FBR) on the basis of the resulting plutonium will produce U-233 from thorium;

3) advanced heavy water reactors will operate at U-233 and thorium, getting 75% of energy from thorium. Spent fuel will then be processed to recover fissile materials and their subsequent processing. [2]

Japan

Japanese experts are currently working on the government order a miniature nuclear reactor that could eventually be used to supply power for residential homes and even colonies on other planets. And if the second field of application is rather fantastic, the mini-nuclear power plant in the basement of a block of flats could become reality soon enough. Developed Rapid-L reactor at a height of 6 m and a width of 2 m, is capable of producing up to 200 kW of electricity, enough to power the office skyscraper or apartment building. According MitsuruKambe (MitsuruKambe), leading a group of researchers at the Central Research Institute of Electricity (CRIEPI), future reactors such as Rapid-L will be widely used simply because a large nuclear power plant will be difficult to build because of the lack of space to house them. Mini-reactors can also be used to compensate for peak loads in large urban areas such as Tokyo Bay. The principle of Rapid-L operation is traditional, but instead of carbon rods used in large reactors to regulate the intensity decay of uranium in the mini-reactor, liquid lithium-6 - lithium isotopes is used, better than any other absorbing neutrons. Inside the reactor there are tubes that filled with inert gas. Above the tubes there are capacities arranged with lithium-6. At higher temperatures metal expands and travels down the tubes, and absorbing neutrons by slowing the reaction. That is the way when the lithium-6 acts as a "liquid rod", of course, that in this case the need for complex mechanical drive for lowering and lifting hard rods, disappears. Operating temperature is Rapid-L 530c, and cooling is effected with liquid sodium. Reactor, according to developers, is completely safe, but to convince the inhabitants of the "nuclear" safe at home in the basement of the reactor will not be so easy. [3]

Norway

Norwegian company AkerSolutions acquired the patent of Rabbi (Rubbia) on the use of thorium fuel cycle, and which experts are currently working to develop a small-sized energy thorium reactor based on proton accelerator. Successful implementation of this project, estimated at $ 1.8 billion, could lead to the creation of a network of tiny underground reactors generating 600 MW of power each. The small size of these reactors stipulates that to ensure its safety and maintain the health there will be spent considerably less money than on the provision and maintenance of large-scale nuclear power plants. The idea and the patent technology using thorium as fuel for reactors based on proton accelerators belongs to Nobel laureate Carlo Rabbi (CarloRubbia), former director of CERN. Small-sized particle accelerator produces a beam of protons that bombard the target of heavy metal embossing while free neutrons. Thorium is the best option of the target material, it is able to allocate a lot of neutrons in contact with him in a high-energy neutrons. [6]

Institute of Energy Technology IFE is testing fuel for the Norwegian company «ThorEnergy». Preparation for the test was carried out for a long time, and according to preliminary estimates the project will be delayed for five years. During this period, the main purpose of the experiment was to secure production process. The results obtained at the end of the project will lay the groundwork for future use of thorium in nuclear industry.

Fuel patented by company «ThorEnergy», consists of 90% to 10% of thorium and plutonium, and therefore differs from the conventional uranium fuel. Studies have shown that the reserves of thorium in the area of the ore field Fensfelte can give a hundred times more energy than all located on the Norwegian continental shelf oil and gas fields. The report submitted by the Norwegian company «ThoriumThinkTank», also showed encouraging results. According to the report, Norway has one of the largest deposits of thorium in the world, and it is estimated that around 56,000 Fensfelte are deposits -675.000 tons of this radioactive element. The program of the experiment will last for five years. For the experiment, the German Institute for Transuranium Elements has made eight pellets of mixed thorium-plutonium fuel. For the next stage of the pilot program is expected that the UK will be made "fully prototype pellet" of such fuel.[7] From the Institute of Posts IFE, which is a research reactor HBWR, it becomes clear - words "the first time in history" are applicable to this program. For the first time in the history of the Institute IFE, orders on irradiated fuel for a Norwegian client are carried out. [8]

Advantages of Thorium Cycle [4]

1. Thorium is in 3 ... 4 times more common element in the earth crust than uranium.

2. Natural thorium consists of a single isotope and its involvement in the fuel cycle, in contrast to uranium does not require time consuming separation of isotopes.

3. Thorium has some more attractive nuclear properties compared to uranium (the resonance integral - average cross section for intermediate energy neutrons is one third of that of the uranium -238, etc.). Therefore, the thorium fuel can be used in thermal breeder reactor.

4. Thorium fuel has some favorable physical and chemical properties that improve the operation of the reactor. By comparison, for example, the most common reactor fuel based on uranium dioxide (UO2), thorium dioxide (ThO2) has a higher melting point and, in contrast to uranium dioxide, is not susceptible to oxidation.

5. As U-233 produced in thorium fuels inevitably contaminated by U-232, the nuclear fuel in some measure protects itself from theft. Radiological hazard of such materials requires the use of remote processing. Long-term radiological hazard commonly used nuclear fuel based on uranium and plutonium is determined by minor actinides. Thorium is more attractive and it may be applied in the mixed oxide (MOX) fuel reduction when the accumulation of transuranic elements is achieved.

6. Unlike plutonium, U-233 can be easily denatured by mixing it with a natural or depleted uranium.

7. Nuclear reactors on the thorium fuel are safer than uranium, because thorium reactors does not possess reactivity margin. Therefore, there are not any destruction of the reactor equipment that could cause an uncontrolled chain reaction.

8. spent fuel elements do not require reprocessing, which significantly reduces the risk of pollution;

9. plutonium problem of accumulation disappears and, consequently, problem of its propagation also disappears (in the form of arms);

10. You do not need to create new reactors, but rather upgrade existing for loading fuel rods with new fuel;

11. Thorium reactors have high internal nuclear safety. Thorium alloys with small additions of weapons-grade uranium and plutonium in nuclear safety and does not require special measures for storage. They are dangerous only in relation to the radiation, but this property can serve as an additional safeguard against theft.

Disadvantages of Thorium Cycle [4]

1. Thorium - trace element which does not form its own ores and deposits.

2. Opening of monazite - the process is much more complicated than opening the majority of uranium ores. Production of thorium is difficult. Therefore, thorium compounds and more similar products based on uranium.

3. Because of the poor mechanical properties of thorium from it impossible to make any precise form of the product.

4. Unlike uranium, natural thorium contains no fissionable isotopes; to achieve criticality the fissile material must still be used (at least initially): uranium-235 or plutonium.

5. Using the thorium in the open fuel cycle in order to achieve the neutron efficiency it requires a high degree of burnout. (Although burning 170,000 MWt·day dioxide / t in the reactor FortSt. Vrain GeneratingStation was deep, however, it is difficult to achieve high degrees of burn-in light water reactors, ie, in the main existing modern nuclear power reactors). If solid thorium is used in a closed fuel cycle, in which the U-233 is recycled, the intensity of the radiation (g-radiation rigid with energies up to 2 MeV) necessitates remote control of all operations of the fuel cycle, which increases the cost compared with the uranium fuel cycle.

6. Compared with the existing methods of processing debugged perfectly uranium fuel this technology for thorium - is still being developed.

7. Although the harmful effects U-232, US apparently experienced bomb through U-233. Therefore, the transition to thorium power does not remove the problem of the proliferation of nuclear weapons.

8. Although thorium fuel produces less long-lived transuranic elements than uranium-based fuel, some long-lived actinides cause long-term radiological impact, especially Pa-231.10. You can make a general conclusion that the thorium cycle is simply more expensive uranium. Besides, it's all worked out poorly.

Neutron-Multiplying Properties of Different Types of Fuel in the Cell of Reactor VVER-1000

We need to evaluate the possibility of using thorium in thermal reactors VVER. To do this, let`s compare multiplying (neutrons) cell properties of thorium reactor fuel. For the realization of the thorium fuel cycle it is necessary to use traditional fissile isotopes of uranium and / or plutonium. Here are such kind of materials:

- A high value of uranium enrichment;
- Weapons-grade plutonium;
- Reactor-grade plutonium extracted from spent nuclear fuel with high burnup.

As the fuel composition can be chosen:

- Traditional dioxides uranium, plutonium and thorium;
- Perspective nitrides (carbides) of these nuclides having a substantially higher density than dioxides.

Take the unit cell of the VVER-1000 reactor of the following type: calculation model is an infinite height unit cell pressurized water reactor consisting of a fuel rod and the surrounding water coolant. Real hexagonal cell in the calculation is replaced by an equivalent cylindrical cross-sectional area which is equal to the area of real cells.

1	2 – core fuel rod	3	4 –moderator (water)

0 0,07 0,39 0,455 0,693 R, см

The core of the fuel element (zone 2) has an outer radius of 0.39 cm with internal diameter of 0.07 cm hole (zone 1). Zone 3 describes the cladding; zones 4 and 5 represent the water coolant (and moderator). Cladding of VVER-1000 reactor is made of zirconium alloy with an outer diameter of 0.91 cm and a thickness of 0.65 cm. Pellets of uranium dioxide has an outer diameter of 0.78 cm and an axial bore diameter of 0.14 cm. Step arrangement of fuel rods - 1,275 cm. The material composition of the basic version was introduced by fuel rods with uranium dioxide density 10.5 g / cm3 and 4.5% enrichment 235U. Cladding - zirconium alloy with 1% niobium. Corresponds to the density of water pressure of 16 MPa and a temperature of 300 ° C.Neutronic calculations were performed using a one-dimensional cell program WIMS-ANL with 69-group library ANL (WIMSD-5 with a library ENDF / B-VI.7). Clarifying calculations will be carried out on the three-dimensional precision program MCU-PTR. Calculation program WIMS-ANL showed that the highest burnup give the following fuels: a mixture of oxides of weapons-grade plutonium and thorium (PuO2 (O) + ThO2), nitride fuel - a mixture of nitride plutonium and thorium nitride (PuN + ThN), a mixture of uranium oxide with 90% enrichment (UO2 (90%) + ThO2) and plutonium mixed oxide, and thorium (PuO2 (E) + ThO2).

Findings

At this stage the result of the performed work consist of subject information gathering, analyzing the advantages and disadvantages of the thorium fuel cycle, ways to use thorium reactors in different countries and ways of realization of the thorium cycle, conducted a preliminary calculation of the most profitable fuels containing thorium. Calculation in program WIMS-ANL showed that the highest burnup was reached among the following fuels: a mixture of oxides of weapons-grade plutonium and thorium (PuO2 (O) + ThO2), nitride fuel - a mixture of nitride plutonium and thorium nitride (PuN + ThN), a mixture of uranium oxide with 90% assay (UO2 (90%) + ThO2) and plutonium mixed oxide, and thorium (PuO2 (E) + ThO2). In future this work will be linked to the evaluation of the effectiveness of these fuels using MCU-PTR and technical specification and dimensions compact reactor operating thorium.

Literature

1. Thorium in nuclear reactors: physics, tehnolgy, safety. Shamanin I.V., Koshelev F. P., Ukhov A. A. Textbook. Tomsk: Publishing house TPU, 2001
2. India builds thorium nuclear reactor. Electronic resource. URL: http://geektimes.ru/post/15-457/(date of treatment 17.01.2014g.)
3. Innovation. Nuclear reactors thorium electronic resources. URL: http://world.lib.ru/w/ wasilij_i_p / txt-4-.shtml. (Date of treatment 17.01.2014g.)
4. Development of miniature thorium reactors can save the world from oil dependence - Electronic resource. URL: energy / 1-0- -razrabotka-miniatyurnyx-torievyx-reaktorov-mozhet-izbavit-mir-ot-neftezavisimosti.html (date treatment 20.11.2014g.)
5. E. Greaves: Thorium Molten salt reactor. Electronic resource. URL: http://www.youtube.com/watch? v = 4MEpkF_5qVQ & feature = youtu.be (date treatment 24.11.2015g.)
6. In Norway, built the first nuclear reactor that runs on thorium - Electronic resource. URL: http://the-clu.com/2013/07/08/1-0-5 (date treatment 01.12.2014g.)
7. thorium-plutonium in norvezhski- electronic resources. URL: http://www.atomic-energy.ru/smi/2013/07/10/42724 (date treatment 01.12.2014g.)

8. Thorium reactor in Norway - electronic resources. URL :: http://publicatom.ru/blog/energy/5817.html (date treatment 01.12.2014g.)

Elimination of insomnia with LED

Martynenko E.I., Denisevich A.A.
ahmedek@mail.ru

Scientific adviser: Denisevich A.A., department of electronics and automation of physical plants, TPU

1. Description of the physical phenomena on which the installation is functioning.

If a person wants to sleep, he needs 8 hours of sleep. Man cut this rate to six hours a day, because he is watch TV and use the computer in the evenings. It can cause many diseases. Melatonin is a regulator of sleep in the body. Its concentration is increased in the evening and at night, and induces sleep. It is facilitates sleep. Melatonin is a hormone. It is pharmacological discovery of the last century. Melatonin is used today for the treatment and prevention of many diseases.

Melatonin has the following functions:

- facilitates sleep, restores rhythm of sleep;
- has anti-stress properties;
- slows the aging process;
- enhances immunity;
- participates in the regulation of blood pressure, gastrointestinal function, work cells of the brain, cerebration;
- has the antitumor effect;
- eliminates the headache;
- involved in the regulation of body weight.

Raising and lowering the concentration of melatonin is controlled by the amount of light. When it gets dark, melatonin increases, and we want to sleep. Bright light inhibits the production of melatonin. Blue light with a wavelength of 446-477 nm suppresses melatonin synthesis. blue colors predominate in the daytime, when a person is awake. Light is yellow-orange in the evening, and the synthesis of melatonin increases, the body is prepared for bed.

This formula is the color temperature of light

$$\text{Color temperature} = 0{,}0029/\ \text{Wavelength}$$

It is about 6500 K.

$$0.0029/6500=4.461*10^{-7}\ (\text{m}) = 446\ (\text{nm})$$

This corresponds to a wavelength of fluorescent light.

If you look at a color temperature of your monitor or TV, most likely it is 6500 K - This value is set by default. Light that is emitted by them suppresses melatonin synthesis.

The solution is to eliminate the use of computer, mobile and TV in the evening.
If a sleep disorder is already present, or you are running on the computer in the evening, you can use our installation.

2. Installation design

The installation contains 32 LEDs: 8 white, 8 yellow, 8 orange and 8 blue. White, yellow and orange LEDs are used for better sleep, and blue LEDs are used to waking up. B You want to sleep, press the button. First, all LEDs are on, and the light is warm, so, it