THERMONUCLEAR ENERGY IS A FUTURE SOURCE OF ENERGY

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Annotation

With the development of nuclear physics, the problem of getting energy from nuclear fusion is topical nowadays. Despite all the difficulties in implementation, thermonuclear energy is a highly efficient source. Therefore, this kind of energy can become a base of economical potential of the country.

Key words: nuclear fusion, nuclear physics, energy, efficiency, sources, reactor.

Research field: nuclear physics.

Related science: nuclear chemistry.

Introduction

Energy production is the main problem of country’s economy. There are several types of getting energy. Recent research in high energy plasma physics shows that nuclear fusion is the energy source that may provide the basis of a future sustainable energy system.

What is the thermonuclear energy?

Thermonuclear fusion is quite similar to most chemical reactions as two initial substances are combined together to create a number of new products. The energy released is called thermonuclear energy.

$${}_1^2H + {}_1^3H \rightarrow {}_2^4He + {}_0^1n \quad (1)$$

In thermonuclear fusion matter transforms into energy, according to mass defect which allows fusion to release energy. The mass of the initial reactants is greater than the mass of the final products and, as Einstein proved, the energy of material is proportional to the composition of the mass of the material and the square of the speed of light: $E = mc^2$ (2).

Whilst nuclear physics seems rather exotic and somewhat strange, actually it is as natural as photosynthesis in plants. Energy from fusion reactions is the basic form of energy in the universe. For example, nuclear fusion is the process which provides the existence of the stars. Our sun is a common example of natural nuclear fusion.

The main problem of realization of fusion is that the two reactants are both nuclei. It means that they are both positively charged bodies which are needed to join together. This presents a problem as similar charges repel each other. Only nuclei at extremely high temperatures have enough kinetic energy to overcome this potential barrier and so this is where the term thermonuclear fusion comes from.

Advantages and disadvantages of fusion

Thermonuclear fusion, as a major new source of energy, would have certain intrinsic advantages:

- the basic fuels (D, Li) are non-radioactive, plentifully available and fairly evenly distributed throughout the Earth's crust ;

- a runaway fusion reaction is intrinsically impossible. Furthermore, once its supply of fresh fuel is cut-off, the reactor can continue operating for only a few tens of seconds ;
- there are few radioactive waste problems: fusion generates no radioactive ash, and the unburnt gases are treated on site. Structural components of the reactor which have become radioactive through exposure to the neutrons will have been placed in storage - but, provided they are made of carefully-selected materials, the storage time could be less than one hundred years. [2]

Additionally, the choice of materials used in a fusion reactor is less constrained than in a fission design, where many materials are required for their specific neutron cross-sections. This allows a fusion reactor to be designed using materials that are selected specifically to be low active, materials that do not easily become radioactive. Vanadium, for example, would become much less radioactive than stainless steel. Carbon fiber materials are also low-active, as well as being strong and light, and are a promising area of study for laser-inertial reactors where a magnetic field is not required.

In general terms, fusion reactors would create far less radioactive material than a fission reactor, the material it would create is less damaging biologically, and the radioactivity "burns off" within a time period that is well within existing engineering capabilities for safe long-term waste storage.

Fusion power could easily satisfy the energy needs associated with continued economic growth, given the ready availability of fuels. There would be no danger of a runaway fusion reaction as this is intrinsically impossible and any malfunction would result in a rapid shutdown of the plant.

However, although fusion does not generate long-lived radioactive products and the unburned gases can be treated on site, there would be a short- to medium-term radioactive waste problem due to activation of the structural materials. Some component materials will become radioactive during the lifetime of a reactor, due to bombardment with high-energy neutrons, and will eventually become radioactive waste. The volume of such waste would be similar to the corresponding volumes from fission reactors. However, the long-term radiotoxicity of the fusion wastes would be considerably lower than that from actinides in used fission fuel.

There are also other concerns, principally regarding the possible release of tritium into the environment. It is radioactive and very difficult to contain since it can penetrate concrete, rubber and some grades of steel. As an isotope of hydrogen, it is easily incorporated into water, making the water itself weakly radioactive. With a half-life of about 12.3 years, the presence of tritium remains a threat to health for about 125 years after it is created, as a gas or in water. It can be inhaled, absorbed through the skin or ingested. Inhaled tritium spreads throughout the soft tissues and tritiated water mixes quickly with all the water in the body. Each fusion reactor could release significant quantities of tritium during operation through routine leaks, assuming the best containment systems. An accident could release even more. This is one reason why long-term hopes are for the deuterium-deuterium fusion process, dispensing with tritium.

While fusion power clearly has much to offer when the technology is eventually developed, the problems associated with it also need to be addressed if it is to become a widely used future energy source. [3]

Fusion reactor

Over the past 50 years, immense progress has been made in the fields of plasma science and fusion technology. Still, harnessing fusion power and delivering it for industrial applications remains one of the greatest challenges of our time.

The problems of getting fuel for a fusion reactor are solved by the organization ITER (originally an acronym of International Thermonuclear Experimental Reactor). ITER is based on the 'tokamak' concept of magnetic confinement, in which the plasma is contained in a doughnut-shaped vacuum vessel. The fuel, a mixture of deuterium and tritium, two isotopes of hydrogen, is heated to temperatures in excess of 150 million°C, forming hot plasma. Strong magnetic fields are used to keep the plasma away from the walls; these are produced by superconducting coils surrounding the vessel, and by an electrical current driven through the plasma.

One of the tasks awaiting ITER is to explore fully the properties of super hot plasmas, the environment in which the fusion reaction will occur, and their behavior during the long pulses of fusion power which the ITER machine will enable.

Firstly, it is necessary to understand the course of the fuelling the fusion reaction. Although different isotopes of light elements can be paired to achieve fusion, the deuterium-tritium (D-T) reaction has been identified as the most efficient for fusion devices.

Deuterium can be distilled from all forms of water. It is a widely available, harmless, and virtually inexhaustible resource. Tritium is a fast-decaying radioelement of hydrogen. Tritium is produced when neutrons escaping the plasma interact with lithium contained in the blanket wall of the tokamak.

In fact, a fusion reaction is about four million times more energetic than a chemical reaction, such as coal, oil or gas burning. While a 1,000 MW coal-fired power plant requires 2.7 million tons of coal per year, a fusion plant of the kind envisioned for the second half of this century will only require 250 kilos of fuel per year, half of which is deuterium, the other half is tritium.[4]

Economical efficiency

This project is highly important for economical development of our country. The General Director of the International Organization ITER Professor Osamu Motojima emphasized the importance of this project:

«50% of the population of our planet lives on the territory of the countries, participating in the project, and these countries account for 80% of domestic product. The figures show how much the project is important not only for science, but also for the world economy. Now the mankind is on the threshold of a new era of fusion energy». [5]

We can also notice that the central role of energetics in our economic structure clearly shows itself for 10 years after the oil crisis. The nuclear energy is a reliable source for the nearest future, and the fusion energy is a huge potential for a more distant time. [6]

Physical protection

One of the principles in the field of nuclear energy is to ensure the safety of its use, the protection of individuals and populations, as well as the environment. Therefore, an examination of the alleged physical protection system of this nuclear facility is required.

In this paper the main criteria for a physical protection system (PPS) of a hypothetical power plant, based on nuclear fusion is identified. The regulatory framework is considered with respect to realization of PPS for a nuclear facility. The aim of PPS according to the Order number 550 is to prevent unauthorized actions with respect to nuclear materials, nuclear facilities and other items PP on nuclear facilities [1].

Talking about thermonuclear facility, nuclear power plant (NPP) is meant as it has the structure analogous to PPS.

To create an effective physical protection system it is essential to identify the object of physical protection, analyse the consequences of unauthorized actions, and foresee possible targets of adversary.

Similarly to the objects of the physical protection of nuclear power, the objects of thermonuclear facility will be:

1) Power facility

2) Fuel

1. The aim of the adversaries is to incapacitate the hypothetical power station by means of sabotage. This can be done through the direct exposure or disfunction of the station, concentrating the magnetic field. All these might result in the station closedown or an accident. Consequently, the PPS should provide sufficient protection barriers to prevent sabotage.

2. The fuels used in the fusion process, are tritium, deuterium and lithium. Tritium and deuterium are expensive elements that enhance attractiveness of these materials to the offender. Volume and mass of fuel needed to release energy are significantly less than it is needed for the object based on nuclear fission, which simplifies the theft of resources. Deuterium and tritium, with a special treatment, can be used as a resource for the development of a nuclear explosive device or radiological weapons. Therefore, the development of an effective system of control and accounting of nuclear materials is essential.

At the final stage there is no spent nuclear fuel, so additional monitoring is not required. In this way it differs from nuclear power stations. The major hazard may come from irradiated materials, because of powerful stream of neutrons produced by the reaction. However, the handling procedure of the irradiated materials for their further application is too complicated and expensive. Besides, there is the factor of self-protection of the material. Therefore, control of nuclear waste isn’t required at the level which provides the security of spent fuel facilities operating on nuclear fission.

As it can be seen, there is need for an effective PPS, based on such factors as self-protection of waste, high cost of fuel, possible operating irregularity of the facility.

Conclusion

Thermonuclear fusion appears to be an ideal method of generating electricity for our growing needs. It is an environmentally friendly energy source, which produces no greenhouse gas. Besides, the materials for reaction are widely available. Thermonuclear fusion is controlled easier than nuclear fission, therefore it is safer. It produces no nuclear waste, which can be dangerous for hundreds of years and may be attractive to adversaries.

We all know that sources of our planet are not infinite and our generation should find a new effective way to produce energy. Perhaps, thermonuclear energy will become the one.

References:

1. Huges, P. (2005) “Thermonuclear fusion”
2. http://www.fusion-eur.org/fusion_cd/popu.htm
3. http://www.world-nuclear.org/info/Current-and-Future-Generation/Nuclear-Fusion-Power/
4. https://www.iter.org
5. http://scientificrussia.ru/partners/sibirskoe-otdelenie-ran/kak-sobrat-termoyadernyj-reaktor
6. http://hizdis.ru/oblushenie/teplonos68.htm
7. Tomsk Polytechnic university, (2009) Regional Training Course on Physical Protection of Research Reactors