ISSN: ۲٦۷٦-٥۷٦٤
www.jocrisar.ir

مجله پژوهش های معاصر در علوم و تحقیقات
سال ششم، شماره ۵۸، اردیبهشت ۱۴۰۳

Review and explanation birth basics of tritium and its fuel cycle

Mohammad Sedigh[۱]

[۱]Master ‘s degree in nuclear physics, Shahrood University of Technology

Abstract

The amount of tritium created in the blanket cover for each reactive neutron Is called the tritium birth ratio (TBR).Until now, it has not been possible to design a cover with a TBR greater than 1/15. The melting fraction depends on the triple product of Tnτ.By emitting an electron from the nucleus, tritium undergoes beta decay and becomes a helium-3 nucleus , which has 1 proton and 2 neutrons. There for, tritium is radioactive and the necessary safety precautions must be taken in the fusion reactor. Tritium is removed from the Tokamak in two ways. Either by Vacuum pumps that are pumped towards the deflector or they are dischared through the primary wall and fertile cover, The amount of tritium in fusion is much larger than in fission and there is no experience in large amount of tritium contamination Isotope separation is done by cooling gases to liquid helium temperature and selective heating in four Coupled distillation columns. In addition, the water in the ether facilities and the air in the buildings pass through a purification machine to remove the tritium in them. Heat pumps maintain a Vacuum in the body of the device. These pumps have porous carbon surfaces that are cooled by liquid helium at a temperature of 5k.

Key words: Tritium, TBR, fusion, Tokamak , pump, Deuterium, blanket cover, ITER, Isotope, Helium, Melting fraction, Plasma.

Introduction:

Tritium one of the isotope of hydrogen have to one proton and two neutrons. Tritium is an unstable isotope that undergoes beta decay by emitting an electron from the nucleus and by losing a negative charge in this reaction, it converts a neutron 0f the nucleus into a proton and thus turns into a helium-3 nucleus.

Helium-3 isotope has two protons and one neutron. Therefore, tritium is a radioactive substance or unstable isotope. Tritium reacts with deuterium and nuclear fusion occurs as a result of this reaction.

Deuterium is a isotope with 1 proton and 1 neutron. blanket cladding designs can provide the necessary tritium to maintain optimal performance of a D-T fusion reactor to produce.

Birth of tritium:

The tritium birth rate (TBR) indicates the amount of tritium produced. When a fusion reaction takes place between a tritium nucleus and a deuterium nucleus in the plasma, a neutron, an alpha ray and a energy of 17.6 Mev are released. The produced neutron must produce more than one tritium nucleus for re-injection into the plasma. Because some tritium is lost in this process.The additional tritium should be kept in order to increase the tritium reserve to operate the reactor at higher power or to supply fuel to other fusion reactors. The number of tritium created in the blanket per each reactive neutron is called tritium birth ratio (TBR).

So far, it has not been possible to design a blanket with a TBR greater than 1/5. as a result, significant birth of tritium is p0ssible only with reactor operation after many years. This period of time is long because only a small percentage of the tritium injected into the plasma can react with the deuterium and most of than are removed and recycled through the deflector. Figure (1) shows the time needed to double the amount of tritium. The vertical axis represents TBR and the horizontal axis shows the percentage of tritium-deuterium fusion. The one-year cure shows that it is impossible to double the amount of tritium in one year, because the curve never reaches the lower limit of the practical TBR range. The curve related to 5 years is difficult and only able to do it under the condition that it can reach the value of 0.05 tritium-deuterium fusion fraction.

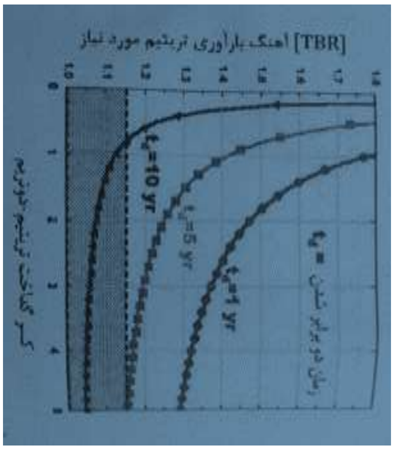


Figure (1): curves related to the doubling time of tritium inventory compared to TBR and tritium-deuterium melting fraction[1]

It takes about 1 years for the amount of tritium to double in the early tokamaks and before the proper deflectors were developed in the tokamaks. The tritium-deuterium fusion fraction was much larger than these values due to recycling. Plasma ions with walls they collide with the vacuum chamber and are converted into neutral gas by recombination. This gas flows back into the plasma, causing ionization and reheating. As advanced deflectors work wall, the ions are prevented from hitting the wall. Instead, the ions are directed toward the deflector goes and they become neutral gas by recombination. Then they will be pumped out of the chamber before entering the plasma again. In the tokamak reactor, the tritium-deuterium fusion fraction is 0.0 0/3, which is unaccepted for reactors [1].

Since the fusion fraction depends on the triple product 0f Tnτ,this parameter is also one of the other signs of the distance between experimental other and a commercial fusion reactor can produce about 2-3 kg of tritium annually. Tritium also decays by 0/05.5 per year and its amount is continuously reduced. We need about 10kg to start the demo device. The ITER reactor alone will consume most of the world,s tritium.

There for, we must develop advanced fertile coatings to achieve higher TBRs in the short term.

Basics of tritium:

Tritium has two extra neutrons compared to hydrogen and is an unstable nucleus. In fact, tritium undergoes beta decay by emitting an electron from the nucleus. The loss of a negative charge in this process causes a neutron in the nucleus to become a positive charge(proton). In order, the tritium nucleus turns into a helium-3 nucleus, which has two protons and one neutron. There for, tritium is radioactive and the necessary safety precautions must be taken in a fusion device. Fortunately, the electron emitted from tritium has a low energy (about 19 Kev) an electron with this energy is not able to penetrate the skin and even in the air it has a range of only about six millimeters.

How ever,the electron caused by the decay of tritium is harmful if it enters the body and there for it sh0uld be stored in water sources, contaminated with tritium, be carful.

Unlike, fission products, tritium has a short half-life of 12/3 years [2].

This means that the amount 0/05.47 of that is converted into harmless helium annually.

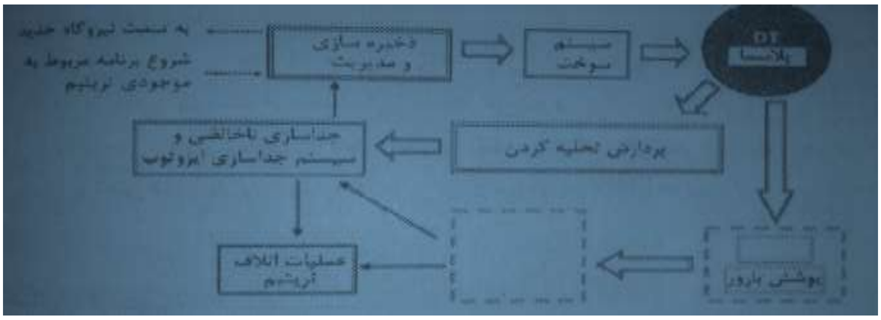
Due to its short life span, a very small amount of tritium is found in nature, about 200 grams of tritium are abtained from cosmic rays per year and about 4 kilograms (kg) of natural tritium are found in the earth,s atmosphere. The amount of man-made tritium reaches about 40 kg.

In comparison, you can he saw that about 1 kg of tritium is needed to run an ether device with DT fuel and a reactor will consume about 100 kg of tritium annually.

tritium fuel cycle:

One of the most complex engineering tasks is the management of tritium supply. After tritium is injected into the plasma, this substance moves from the plasma valume to the deflector due to the activity 0f the pumps. Also tritium is produced in the blanket, which must be trapped and purified. Be extra tritium it should be stored with complete safety for later use in the reactor or the start-up of other reactors.

Figure (2) shows a diagram of the tritium recycling cycle.



Figure(2): A simple plan of the tritium fuel cycle[1].

Tritium is removed from the tokamak in two ways. Either by vacuum pumps that are pumped towards the deflector or through the primary wall and blanket. The output of the vacuum pumps directly ends up in an isotope separation system that separates T_2, D_2 and ${}^4_2He$ from it separates impurities.

Then the pure tritium is sent to the tritium storage and management part. The tritium produced in the blanket is also first transferred to the tritium birth system to separate and remove it from the generative materials and then it will go to the isotope separation part. In the next step, the materials contaminated with the tritium goes to the tritium waste management section. The reactor fuel system receives recycled tritium from the two mentioned methods as well as storage or from external sources. Then the fuel system injects tritium and deuterium into the plasma. Cheap deuterium and it is safe and its recycling is not economical . the vacuum in the device core is maintained by cryogenic pumps. These pumps include porous carbon surfaces that are cooled by liquid helium at a temperature of 5 k. at this temperature, all gases except helium are condensed and reach the surface refrigerant sticks.to release hydrogen containing tritium, cryogenic pumps are heated inter mittiently to a temperature of about 90k and then the gas is sent to the isotope separation system. To release all trapped gases, the pumps are heated to room temperature. Isotope separation is performed by cooling the gases to liquid helium temperature and selective heating in four coupled distillation columns. It consists of seven floors[3]. In addition, the water in the ether facilities and the air in the buildings pass through a purification machine to remove the tritium in them. To store the tritium, they are passed through metal hydride beds. Each of these beds has the ability to hold 100gr of tritium. Zirconium-cobalt absorbs tritium to from $ZrCoT_2$, although there are no methods to remove tritium pollution in the nuclear fission industry, the amount of tritium in fusion is greater than that of fission and there is no experience of large-scale tritium contamination.

Conclusion:

When a fusion reaction takes place between a tritium nucleus and a deuterium nucleus in the plasma, a neutron is abtained. The produced neutron must produce more then one tritium nucleus to be re-injected into the plasma, because some tritium is lost in this reaction and tritium additional should be in order to raise the storage of tritium direction starting the reactor at a higher power or maintaining the fuel supply of other fusion reactors. Deuterium-tritium melting fraction is equal to 0/0 0.3 for reactors is unacceptable. An important issue in fusion metal reactors is the fraction of tritium-deuterium fusion, which is abtained from the triple product of $Tn\tau$.

The amount of tritium in fusion is much larger than in fission. In nuclear fusion reactors, the production and supply of tritium must be managed. The excess tritium is removed from the tokamak into ways:1- by vacuum pumps that are pumped to the deflector, 2- through the primary wall and blanket.

Thanks:

I am deeply grateful to my honorable professors, Dr. Hassan Hassanabadi, Dr. Alireza tavasoli and Dr. Yasaman Nasirzadeh, who always encourage me.

References:

1- M. Abdou, 2009,Challenges and development pathways for fusion nuclear science and technology

2- M. Glugla et al., Review of the ITER fuel cycle systems and recent progress. Symposium on Fusion Energy, San Diego, CA, June 2009

3-I.R.Cristescu,2004,The Fuel Cycle System(International School on Fusion Reactor Technology, Erice Italy