USING OF NUCLEAR FUSION FOR ELECTRICITY-PRODUCING FUSION POWER PLANTS

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ABSTRACT

In conjunction with worldwide decreasing of energy sources and increasing of electric power consumption, the environment problematic is getting into spotlight more and more presently. Due to these facts, it is necessary to search new energy sources and new solutions of energy power generation. As one possibility appears nuclear fusion, but there are a lot of problems with this technology nowadays. This paper deals with basic facts about this phenomenon.

1. INTRODUCTION

Nuclear fusion is the process by which multiple atoms having the same charge join together in order to form a heavier nucleus. In some cases, depending on the mass, energy can be released or absorbed during this process. Nuclear fusion is a very important energy source. Nuclear fusion as a source of manmade energy is still largely in the developmental stage. While some energy from nuclear fusion is manmade, most of the energy coming from nuclear fusion that humans and other life forms benefit from comes from the sun. Nuclear fusion is the process by which all stars generate energy.

2. PHYSICAL PRINCIPLE OF THE FUSION AND THE TOKAMAK

2.1. Nuclear fusion

Nuclear fusion is the energy source of the future. It is what provides the sun and the stars with the energy to shine continuously for billions of years. Fusion has been used here on earth to produce nuclear bombs, but has not yet been controlled so that we can obtain useful energy.

Fusion is what happens when two atomic nuclei are forced together by the pressure high enough to overcome the strong repulsive forces of the respective protons in the nuclei. When the nuclei fuse, they form a new element, and release excess energy in the form of a fast-moving neutron. The energy is "extra" because the mass of the newly formed nucleus is less than the sum of the masses of the original two nuclei. The extra mass is converted to energy according to Einstein's equation $E=mc^2$.

2.2. How it works

The nuclei used by the sun, and in experiments on earth, that undergo fusion, are two isotopes of hydrogen called deuterium and tritium. The simple hydrogen atom, which has one proton in its nucleus, has two isotopes. Similar forms of hydrogen, but with extra neutrons in their nuclei. One is called deuterium, the other tritium (Fig. 1).

Deuterium and tritium are used to form a nucleus of helium and a neutron. This fusion releases 17.59 MeV of energy (Fig. 2).

The problem with generating nuclear fusion lies in getting two atoms having the same charge close to each other. Atoms have the same charge generally repel each other, rather than being brought together. However, once brought together, nuclear force begins to take over. This force will attract the nuclei of two or more atoms toward each other and start nuclearfusion, but this happens only if they are of close enough proximity.

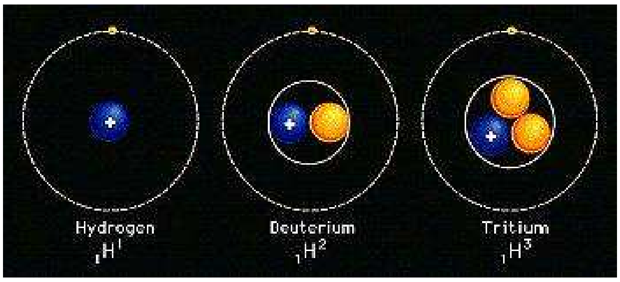

Figure 1 – Hydrogen isotopes [4]

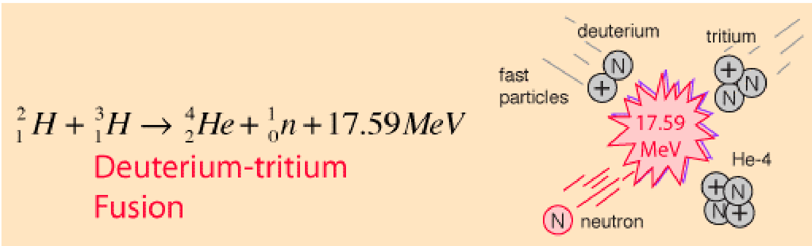

Figure 2 – Nuclear fusion [3]

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2.3. Alternative fuel sources

Since the most practical nuclear fusion reaction for power generation seems to be the deuterium-tritium reaction, the sources of these fuels are important. The deuterium part of the fuel does not pose a great problem because about 1 part in 5000 of the hydrogen in seawater is deuterium. This amounts to over 10^{15} tons of deuterium. Viewed as a potential fuel for a fusion reactor, a gallon of seawater could produce as much energy as 300 gallons of gasoline. The tritium part of the fuel is more problematic - there is no sizable natural source since tritium is radioactive with a halflife of about 10 years. It would have to be obtained by breeding the tritium from lithium.

2.4. Tokamak

Tokamaks were invented in the 1950s by Soviet physicists Igor Tamm and Andrei Sakharov, inspired by an original idea of Oleg Lavrentyev.

The word tokamak is a transliteration of the Russian word токамак, an acronym of either "тороидальнаякамера с магнитными катушками" (*toroidal'naya kamera s magnitnymi katushkami*) - toroidal chamber with magnetic coils, or "тороидальная камера с аксиальным магнитным полем" (*toroidal'naya kamera saksial'nym magnitnym polem*) – toroidal chamber with axial magnetic field.

A tokamak is a device using a magnetic field to confine a plasma in the shape of a torus (doughnut). Achieving a stable plasma equilibrium requires magnetic field lines that move around the torus in a helicalshape.

In a Tokamak, two superimposed magnetic fields enclose the plasma: this is the toroidal field generated by external coils on the one hand and the field of a flow in the plasma on the other hand. In the combined field, the field lines run helicoidally around the torus centre. In this way, the necessary twisting of the field lines and the structure of the magnetic areas are achieved. Apart from the toroidal field generated by the external field coils and the field generated by the flow in the plasma, the

Tokamak requires a third vertical field (poloidal field), fixing the position of the flow in the plasma container. The flow in the plasma is mainly used to generate the enclosing magnetic field. In addition, it provides effective initial heating of the plasma. The flow in the plasma is normally induced by a transformer coil. Owing to the transformer, the Tokamak does not work continuously, but in pulse mode. Since, however, a power plant should not be operated in pulse mode for technical reasons, methods are examined to generate a continuous flow - for example by high-frequency waves. The fusion reactor ITER is also planned according to this principle.

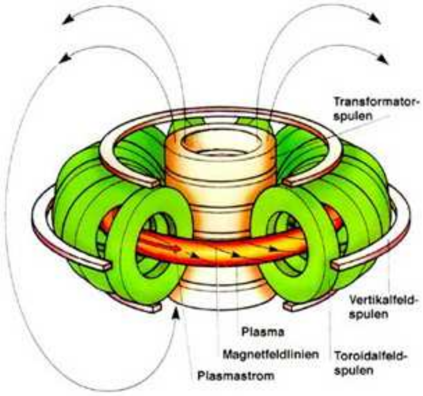

Figure 3 – Tokamak principle [5]

2.5. ITER

Originally the International Thermonuclear Experimental Reactor, pronounced *eat-er*, is an international research and engineering project which is currently building the world's largest and most advanced experimental tokamak nuclear fusion reactor and will be constructed in Europe, at Cadarache in the south of France.

ITER is a device to demonstrate the scientific and technical feasibility for mass energy production based on the nuclear fusion energy research and development for the last forty years and will serve as the stepping stone to the era of commercialized fusion energy.

The ITER Project is the largest international joint research project participated by seven parties for the development of nuclear fusion energy, the best choice to overcome grave issues raised by fossil fuel depletion and global warming. The project's members are the European Union, India, Japan, People's Republic of China, Russia, South Korea and the United States. The EU as host party for ITER will contribute 45% of the cost, with the other parties contributing 9% each.

Overview of the ITER project is shown in a table (Table 1).

Table 1 – Overview of the ITER Project

Project	The ITER (International Thermonuclear Experimental Reactor) Project
Timeline	2004 ~ 2015
Construction Site	Cadarache, France
Objective	Secure Key Technologies necessary for constructing a nuclear fusion power plant by participating in the ITER Project which aims to demonstrate the scientific and technical feasibility of fusion power in concurrence with six other parties (EU, Japan, USA, Russia, China, India)
Mission	Development and construction of ITER generating 500MW fusion power
Management System	Seven parties sharing the responsibility for the ITER construction, ITER Organization Management, Joint R&D and the costs
Construction Cost	3,577.7 kIUA (5,080 million Euro)

The fusion reactor (fig. 4) itself has been designed to produce 500 MW of output power for 50 MW of input power, or ten times the amount of energy put in.

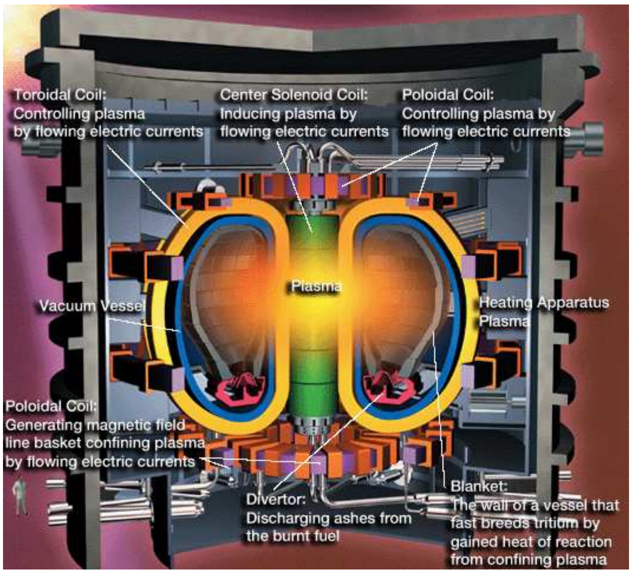

Figure 4 – Construction of the ITER reactor [6]

3. CONCLUSIONS

Nuclear fusion is one of the possibilities of energy power generation of the future. There are a lot of problems which have to be solved, but it is able to say that some efforts like the ITER project proves that this technology could be a solution of environmental and energy crisis.

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