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INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR (I.T.E.R.) – A REVIEW

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Abstract - In today's world, we are facing a problem of energy crisis. The need for energy is increasing with the advancement in technology. Since the conventional energy sources are decreasing day by day, it is getting significant as well as necessary for us to find new energy sources that are available abundantly.

Now the question arises, "which source to be used for handling this energy crisis?" Whether to use the inexhaustible sources such as Solar energy, Wind energy, Hydro-electricity, etc. or to use some other source of energy. As we all know according to the law of energy, "Energy can neither be created nor be destroyed. The total amount of energy in the universe remains constant. Energy and mass are inter-convertible." Nuclear Fusion is based on the principle of Energy-Mass inter-convertibility.

As the name Thermo-Nuclear suggests, I.T.E.R. uses thermal energy generated from Nuclear fusion. Nuclear fusion is a reaction in which two nuclei fuse forming a single nucleus releasing some amount of energy equivalent to the mass difference between the sum of original nuclei and the final nucleus.

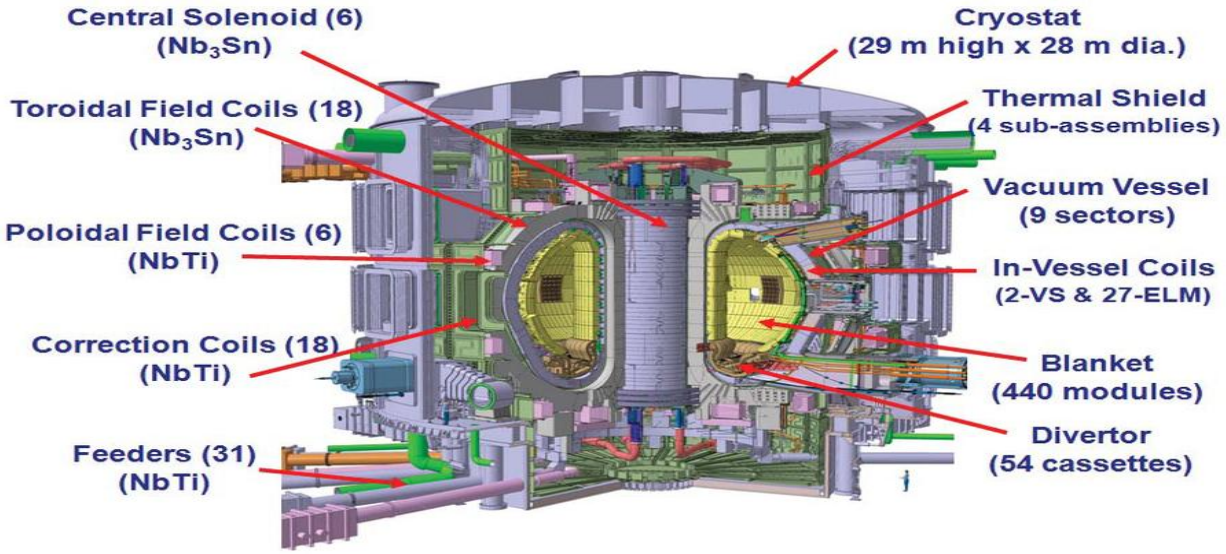
As we are searching for an energy source which is abundant in nature, it becomes necessary for us to decide those two fusing elements which can either be internally produced in the power plant or are available abundantly. I.T.E.R. uses Deuterium and Tritium as the fusing elements. Deuterium and Tritium are two isotopes of hydrogen. Tritium is generated in the plant itself, and Deuterium is generated from water bodies having D2O in large amount. So let's have look at I.T.E.R. project in this paper.

1. INTRODUCTION:

International Thermonuclear Experimental Reactor (I.T.E.R.) is a nuclear fusion power plant. As the name suggests it is experimental. It is a collaboration of six countries and one European Union (EU). It is world's largest nuclear fusion power plant. It is being setup in France, next to Cadarache facility.

I.T.E.R. is run, funded and designed by seven members. The seven members are European Union (EU), India, China, , Japan Russia, South Korea and the United States. The EU being host of the I.T.E.R. project, 45% of cost is contributed by it. Remaining countries contribute about 9% of the cost.

According to USITER, "ITER is a unique partnership of nations jointly responsible for construction, operation, and decommissioning of an experimental fusion facility." I.T.E.R. being an experimental reactor, it will allow study of fusion reaction which governs the Sun and other Stars. The nuclear fusion will take place in the form of Plasma in a Tokamak. Basically, the aim of I.T.E.R. project is to check the scientific and technological feasibility of fusion energy.



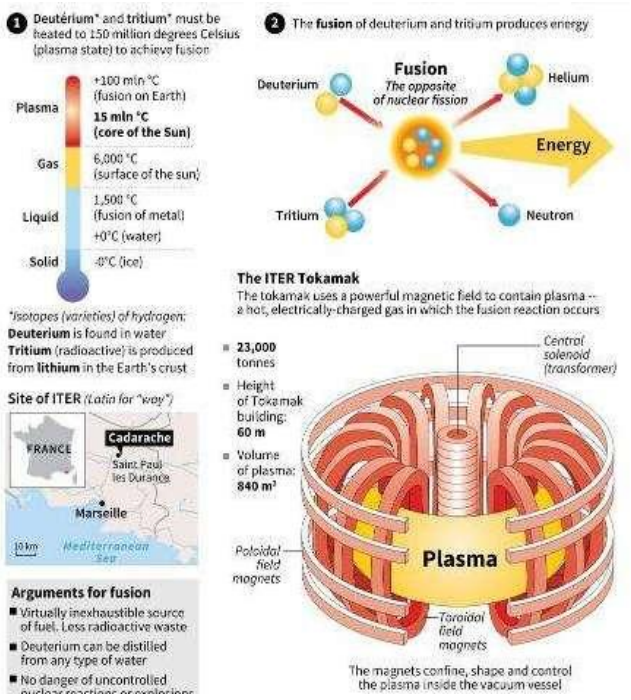
2. DEUTERIUM AND TRITIUM:

Deuterium and Tritium are the two isotopes of Hydrogen. Basically isotopes are those elements that have same atomic number while different atomic mass number. As we all know that the number of electrons and protons are always same in an atom following charge neutrality. But, the number of neutrons and protons are not always same. The atoms which have same number of protons but different number of neutrons (i.e they have different atomic mass number) are isotopes of each other. Atomic mass number of Deuterium is 2 and atomic number is 1, while atomic mass number of Tritium is 3 and atomic number is 1 same as that of Hydrogen.

3. SOURCES OF DEUTERIUM:

Deuterium is produced from Heavy water. An ordinary Light water has two Hydrogen atoms in its molecule. While Heavy water has two Deuterium atoms in its molecule instead of Protium(Hydrogen) atoms. Heavy water comprises mostly(usually about 90%) of Deuterium Oxide(D2O), some amount of Hydrogen-Deuterium Oxide and very less quantity of Hydrogen Oxide(Normal water). Water containing Hydrogen-Deuterium Oxide is called Sem-Heavy water. Ordinary water also has Deuterium Oxide atoms but in very less quantity, about 156 atoms per million hydrogen atoms. Deuterium needs to be extracted from Heavy water.

4. PLASMA:



We know that there are three states; Solid, Liquid and Gaseus. But actually there are four states, the fourth being Plasma. In simple words, Plasma is the highly ionized state of Gas. It has sufficient energy to free the electrons from its atom and let both (electrons and Ion) of them exist in free state. Even though the electrons break from their atoms, they still travel with their nucleus. To our surprise, Plasma exist in a large quantity in the Universe. When a gas is heated to a

very high temperature by passing it through a spark, the gas gets converted to Plasma. In I.T.E.R. project, Deuterium and Tritium are provided very high energy and thus are ionized converting them into Plasma state.

5. WORKING:

I.T.E.R. basically works on the principle of Fusion Reaction. Fusion Reaction is the one which provides energy for all the stars including Sun. Nuclear Fusion in I.T.E.R. project is carried out using Deuterium and Tritium as the reacting elements. These two isotopes react together to give Helium and neutron as bi-product with some amount of energy. The energy released with Neutron is 14MeV while the energy released with Helium is 3.5MeV. The neutron released is further used to generate Tritium in the Plant itself. The neutron reacts with Lithium from the Breeder blanket and releases Tritium and Helium(He) as the bi-product. The energy gain is more than 5.

Reaction:

D2 + T3 ⟶ n(Neutron) + He(Helium) (Deuterium) (Tritium)
(14.4 MeV) (3.5 MeV)
(For T3 production) (As Plasma Heat)

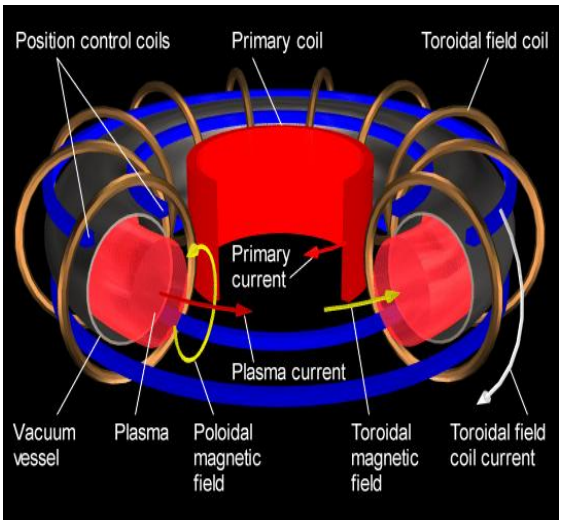
n + Li6 ⟶ T3 + He(Neutron) (Lithium) (Tritium)
(Helium)

6. TECHNICAL COMPONENTS:

The technical components of the I.T.E.R. project are discussed below:

6.1 TOKAMAK

Tokamak is a device which confines the Plasma in a Toroidal shape using magnetic field. Basically, Tokamak is a Russian word. Torus is a shape which is obtained by rotating a closed curvature, for example a circle about a line which is in the plane of circle. Simply, Torus is a tube shaped structure. Tokamak is used in I.T.E.R. project to confine Plasma (Deuterium and Tritium) in Toroidal form.



6.2 MAGNET SYSTEM

Use:
It is used to confine the Plasma in the Tokamak in Toroidal shape. Since Plasma is in ionized form, magnetic field act on the ions which are at a very high temperature, around several million degree celcius.

CONSTRUCTION:
Electromagnetic concept is used to generate magnetic field. That is, magnetic field is generated by passing current through the conductor. The magnetic field produced is of 13.5 Tesla. The current passed to generate this field is 46 kA. The superconducting material used in central solenoid is Niobium-Tin. Toroidal shaped field coils will use Niobium-Tin material as well. Other lower field magnets will use Niobium-Titanium for their superconducting elements.

6.3 CRYOSTAT:

Use:
It is used to provide super cool environment to vacuum where high temperature Plasma will be confined.

Construction:
Its thickness is about 50 mm to 250mm. It surrounds the vacuum vessel and the magnetic system. Its weight is around 3800 tonne. The material used is stainless steel. It occupies a volume of 8500 cubic meter. The total number of modules that will be manufactured are 54. The manufacturing and installation of Cryostat is undertaken by Larsen and Toubro heavy engineering.

6.4 VACUUM VESSEL

Use:
The temperature of the Plasma that is confined by the Tokamak is around several million degree Celcius. Such high temperature Plasma if comes in actual contact with any material, will melt the material. Thus we have to avoid the Plasma from coming in actual contact with any material, this is done by confining the Plasma using magnet system, but heat transfer takes place in three modes i.e. Radiation, Conduction and Convection. Conduction needs medium to transfer heat while radiation takes place without the presence of medium. Thus, if we remove medium(all the elements) between the Plasma and its surrounding component, heat transfer will take place only due to radiation. This will help reducing the rate of heat transfer, thus helping to keep the surrounding temperature low as much as possible. This creates a need of creating vacuum around the Plasma. Vacuum vessel serves this purpose perfectly by creating vacuum around the vessel.

Construction:
Vacuum vessel is a double walled central part of the I.T.E.R. Material used for constructing vacuum vessel is steel. It contains Plasma at its centre. Its constructional significance is that, it is 16 times heavy and 2 times large as compared with any earlier fusion vessels. It weighs 5116 tonnes. Its outer diameter is around 19.4m (64 ft.), inner diameter is about 6.5m (21 ft.). It vertically measures a height of 11.3m (37 ft.). It has three main parts: Main vessel, the port structures, the supporting system. Space between this double walled structure is filled by shield structures made of stainless steel. Its inner surface has breeder modules attached to it which contain breeder blanket. The vessel has 18 upper, 17 equatorial, 9 lower ports for remote handling of operations, vacuum pumping, etc.

6.5 BREEDER BLANKET:

Use:
Tritium is a key element in I.T.E.R. project. Since Tritium is available in very less quantity on earth, we need to produce Tritium in the reactor itself. This generation of Tritium is done in the Breeder Blanket. Thus, it is a significant component in I.T.E.R. project. Tritium can be produced using 2 methods, Helium Cooled Lithium Lead (HCLL) and Helium Cooled Pebble Bed (HCPB). Both will be tested in I.T.E.R. project.

Construction:
It is located adjacent to the vacuum vessel. Material used as breeder pebbles in HCPB include metatitanate and lithium orthosilicate. Breeder material is selected on the basis of good extraction, mechanical stability and low activation levels.

6.6 COOLING SYSTEMS:

The I.T.E.R. project has 3 inter-connected cooling systems. Most of the heat is removed by primary water cooling loop. This loop is further cooled by heat exchanger which is situated in Tokamak building's secondary confinement. Secondary cooling loop will be cooled by a larger complex comprising of a cooling tower, 5 km pipeline supplying water. This water is than released before which it is tested for harmful chemical contamination. Liquid nitrogen does a cooling of 1300kW at 80K, while liquid Helium does a cooling of 75kW at 4.5K. Liquid Helium system will be designed, manufactured and installed by "Air Liquide".

7. LOCATION OF I.T.E.R. PROJECT:

It took a long time for the members to decide the location of I.T.E.R. project. As we know such a big, international project will take a large space for it to get installed, it was an important decision to select its location. Canada suggested Clarington in May 2001 but canceled it afterwards. Spain offered Vandelo's on 17th April, 2002. Most suitable sites were Cadarache in Provence-Alpes, France and Rokkasho, Aomori, Japan. European Union suggested France, but Japan wanted it to be installed in Japan. EU and Japan decided to come to a solution till July 2005. Finally, in Moscow, 28th June, 2005 all the member countries decided Cadarachein Provence-Alpes-Cote-d'Azur, France as the location where I.T.E.R. project will be installed and run. Construction began in 2007.

CONCLUSION:

If I.T.E.R. project becomes a success, DEMO power plant will be conducted. The project will be a boon to mankind if succeeded. It will demonstrate the efficiency of fusion reaction practically. It will solve energy crisis problem in the world where demand for energy is rising day by day.

8. CITATION:

[1] https://en.wikipedia.org/wiki/ITER
[2] https://www.iter-india.org/
[3] https://www.iter.org/
[4] www.sciencemag.org/
[5] http://phys.org/
[6] http://edution.jlab.org/