Report on the ITER project in Cadarache – June 2011

Introduction

The ITER project is the name given to the design, development and manufacture of a nuclear fusion working test bed, being constructed in Cadarache in Southern France, on a 180-hectare site. The project is an international effort involving funding by 7 countries; namely the UK as part of the European Union, China, India, Japan, South Korea, Russia, and the United States with technical contributions from many others: there are 34 countries contributing to the development in some way. The name ITER originally stood for International Thermonuclear Experimental Reactor, although sensitivities over the expression 'thermonuclear' have caused a re-think and it has been determined that ITER also means "way" or "journey" in Latin and so that is now the accepted meaning – "The way".

It is hoped that nuclear fusion will in the future provide a plentiful supply of virtually pollution free energy using similar technology as is found in our Sun. Although the Sun functions because of fusion, at temperatures below 15 million degrees Centigrade, here on Earth we must use much higher temperatures to compensate for the lower gravitational forces (fusion occurs when the correct density of fuel is raised to a certain temperature) and so the ITER Tokamak plasma will have to reach about 150 million degrees Centigrade to create fusion.

In Europe, Fusion for Energy (F4E) is the European Union's Joint Undertaking for ITER and the Development of Fusion Energy. The organisation was created under the Euratom Treaty by a decision of the Council of the European Union in order to facilitate the following:

- To be responsible for providing Europe's contribution to ITER and is established for a period of 35 years from 19 April 2007 and is located in Barcelona, Spain
- To support fusion research and development initiatives through the Broader Approach Agreement, signed with Japan – a fusion energy partnership which will last for 10 years.
- To contribute towards the construction of demonstration fusion reactors including DEMO and PROTO.

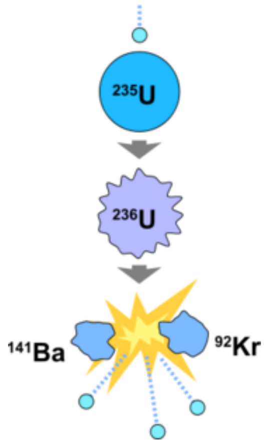
The Council made this choice for several reasons, namely:

- No carbon emissions. The only by-products of fusion reactions are small amounts of helium, which is an inert gas that will not add to atmospheric pollution.

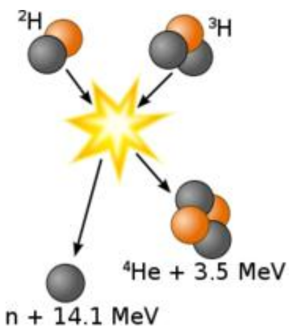
- Abundant fuels. Deuterium can be extracted from water and tritium is produced from lithium, which is found in the earth's crust. Fuel supplies will therefore last for millions of years.
- Energy efficiency. One kilogram of fusion fuel can provide the same amount of energy as 10 million kilograms of fossil fuel.
- No long-lived radioactive waste. Only plant components become radioactive and these will be safe to recycle or dispose of conventionally within 100 years.
- Safety. The small amounts of fuel used in fusion devices (about the weight of a postage stamp at any one time) means that a large-scale nuclear accident is not possible.
- Reliable power. Fusion power plants should provide a base load supply of large amounts of electricity, at costs that are estimated to be broadly similar to other energy sources.

Preamble

There are two basic systems for creating energy at a nuclear level; fission and fusion. Fission is the splitting of a large atom into two or more smaller ones. This is the system used by present day reactors. It uses a relatively simple technology and produces considerable waste in the form of transuranic actinides and irradiated cooling water that retain radioactivity for lengthy periods and must be stored in protective conditions; in some cases for many years. The fuel processing costs are also significant. The diagram to the left shows the atomic reaction with the neutron approaching from the top and reacting with the uranium 235 to form uranium 236 which then divides with the release of a massive energy pulse plus barium 141 and krypton 92 and three free neutrons. The energy available from this release can then be used to create electrical power, via heat exchange, steam turbines and alternators.



Fusion is the fusing of two or more lighter atoms into a larger one. It is a more complicated but theoretically safer system and from the diagram on the right it can be seen that the reaction is also more complex. By combining and burning a deuterium and tritium fuel in a high pressure plasma to produce helium-4, (a non radioactive isotope of helium) and a massive neutron flow from which kinetic energy is collected as heat. The heat is then converted to electrical energy via turbines and alternators in the usual way. The fuel cost is much less, also as deuterium can be collected readily form sea water and tritium can be ‘bred’ in the walls of the reactor by using lithium-6 as a cooling medium and bombarding it with neutrons.



The theory has been around for many years but the real development started in the 1950's. The UK competed with the US to be first to achieve 'fusion'. Towards this end a machine called ZETA was built and run at Harwell. British scientists were precipitous in claiming that they had achieved neutron generation from fusion but had to retract later. ZETA continued to run however and was directly responsible for a number of developments essential to the running of later units in the UK.

The United Kingdom's fusion research programme is based at the Culham Centre for Fusion Energy (CCFE) in Oxfordshire. The work is funded by the Engineering and Physical Sciences Research Council and by the European Union under the Euratom treaty.

The UK contributes to fusion research in two main ways:

- Its own fusion programme, centred on the MAST (Mega Amp Spherical Tokamak device). The UK programme also makes important contributions to ITER preparations and to theory, materials and technology research.

- Operating JET (Joint European Torus), Europe's flagship experiment. JET is situated at CCFE next to the UK's fusion laboratory. CCFE operates the JET facility on behalf of all the partners in the ITER group.

Note that Tokamak refers to a magnetic field containment system for the hot plasma in a fusion reactor: the word derives from the Russian for a toroidal space controlled by magnetic fields.

The ITER project

The agreement for the ITER project was signed by all 7 funding participants in 2006 and work on site preparation commenced in 2007. The facility will provide a fusion and fusion technology related test bed that will help to provide data for the first planned commercial (development) size power station called DEMO to be followed later by PROTO the first commercial operating power station.

The aim of the ITER fusion project is to produce a ten-fold gain in energy, from 50MW input to 500MW output and become a fully working pilot plant that will show the way forward for the development of commercially sized self fuelling generation plants. The current largest fusion reactor only produces 16 MW of power and this is the Joint European Torus (JET), which is located in the UK at Culham, in Oxfordshire.

The ITER project is based on the 'Tokamak' concept of magnetic field confinement, in which the plasma is contained in a toroidal or 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 high temperature plasma/fuel mixture away from the walls that would otherwise be damaged. The magnetic fields will be produced by superconducting coils surrounding the vessel, and by an electrical current driven through the plasma itself. On the inside of the vacuum vessel walls there are many replaceable parts, that form a protective shield or blanket to absorb the energy from neutron bombardment created in the fusion process. This energy is extracted in the form of heat that ultimately is converted to electrical energy.

It should be noted that tritium is not found naturally and of importance is the production of the tritium to be used with deuterium as the fuel. A lithium based cooling (or heat transfer fluid), is present within the blanket and as the lithium is impacted by the neutrons produced, a proportion is converted to tritium. This then is the basis for the self sustaining fuel system: deuterium being found readily and in great quantity in sea water.

The complete vacuum vessel is enclosed in a Cryostat or refrigerated jacket to thermally insulate the components and the superconducting magnet system. The Tokamak diverter situated around the bottom of the vacuum vessel extracts helium ash and heat from the plasma. The heat extracted adds to that from the ‘blanket’ and is used to produce electricity.

Some basic facts about the ITER machine:

It will take 80 000 kilometres of niobium-tin (Nb_3Sn) superconducting strands to build the ITER's toroidal field magnets. This equates to 400 tonnes of multifilament wire.

The ITER Tokamak will be the largest ever built, weighing about 23,000 tonnes with a plasma volume of 840 m^3. This is more than 8 times the size of the fusion machine currently operating in the UK.

104 kilometres of specially modified road known as the “ITER Itinerary”, is to be built to transfer heavy components to the ITER site.

The Tokamak seismic isolation pit will house the anti-earthquake foundations of the future Tokamak complex and will support about 360,000 tonnes including the foundations themselves.

Each of the ITER Tokamak's 18 toroidal field coils will weigh 360 tons.

It took two years to construct the ITER platform which is level, 1000 metres long by 400 metres wide and involved the movement of 2.5 million cubic metres of material.

The complete project was initially estimated to cost 10 Billion Euros (the cost is to be shared by the seven ITER Members (representing 34 countries), over the projected life of the project, namely 30 years

The Broader Approach agreement

The Broader Approach is an agreement between Euratom and Japan covering research and technology activities supporting the ITER project and an early realisation of fusion energy for peaceful purposes. The agreement was signed in Tokyo on 5 February 2007 and entered into force on 1 June 2007.

The Broader Approach covers three large research projects that are to be jointly implemented by Euratom and Japan. Other members of the ITER consortium may, following the agreement of Euratom and Japan, participate in the projects.

The three projects support the operation of ITER and the preparation for a future demonstration of a fusion power plant. They are aimed at securing an early realisation of fusion energy as a clean and sustainable energy source.

The three projects are:

- IFMIF/EVEDA the engineering validation and engineering design of the International Fusion Materials Irradiation Facility (IFMIF). IFMIF will use a particle accelerator to produce a large neutron flux which will subject candidate materials to similar conditions (neutron bombardment) expected to be experienced by the inner wall of a full-scale fusion reactor.

- The International Fusion Energy Research Centre (IFERC) which will house a DEMO Design and R&D Coordination Centre, a major computational Simulation Centre, and a remote experimentation Centre for use with ITER.

- The Satellite Tokamak Programme, which involves the upgrade of the Japanese JT-60 tokamak with advanced superconducting magnets.

All three projects are based in Japan. The main Euratom contributions to the projects will be in-kind resources provided by Member States of Euratom or Associated States. The European Joint Undertaking for ITER and the Development of Fusion Energy (Fusion for Energy or F4E) is responsible for implementing the Broader Approach activities.

Project Status June 2011

New project baseline agreed at the ITER Council meeting in July 28, 2010

• First plasma – November 2019
• First DT (Deuterium/Tritium fuel) – March 2027

NOTE: A new 'currency' was invented for the ITER project and this is the IUA or ITER Unit of Account. In European terms it equates to 1 IUA = 1,552.24 euro

• Costs - New baseline of 4585 kIUA
•Additional Reserve of 115 kIUA => total = 4700 kIUA
Plus contributions of local area – 467 M €
•Operation Cost 188 kIUA/year – sharing will be different
•Deactivation Cost 281M Euro
•Decommissioning Cost 530M Euro
All costs converted to Euros based on 2010 conversion rates.

The 11 March 2011 earthquake and tsunami and subsequent aftershocks that hit Japan, (one of seven partners in ITER), severely damaged key facilities for testing the reactor's components. Unless repairs can be made or work reassigned quickly, the damage could cause a delay of several years (ref Osamu Motojima, ITER's director).

In May, the International Science and Technology Advisory Committee (STAC) convened to discuss the final design of ITER, and the schedule up to 'first plasma'. The Management Advisory Committee (MAC) also met and the recommendations made by these two committees will go to the ITER Council, the supervising body of the ITER project that will meet in Aomori, Japan, on 18 June.

Construction works in Cadarache are roughly on schedule for the above program. The deficiency in computer aided design (CAD) personnel and facilities was identified and resolved by outsourcing the works. It may be possible to recover the delay posed by the Japan earthquake; however we have yet be told the affect that the earthquake will have on this project.

Observation

The opportunity that this project offers to the world is staggering: a power source that is virtually self fuelling and emission free and with no long term hazardous storage issues that beset conventional fission reactors!

The USA fast tracked the 'moon landing' just to compete with Russia: yet here is an opportunity to solve a major part of the world's resource deficiency in one 'hit' and its being left to the scientists to waddle along in their own time; using public funds of course.

Common sense dictates that this project should be fast tracked and that STAC and MAC should be governed by the partner states' energy departments. All progress should be directed on the basis of *'time is of the essence'* in its true contractual/financial meaning. If a technical problem arises then 'money should be thrown at it' instead of at the ludicrous carbon debacle that is destroying the economy of all EU countries and some others worldwide.

Sources of general ITER information:

http://www.iter.org/
http://www.iter.org/mach
http://www.iter.org/factsfigures
http://fusionforenergy.europa.eu/understandingfusion/ourcontribution.aspx
http://www.ccfe.ac.uk/introduction.aspx
http://indico.cern.ch/getFile.py/access?resId=3&materialId=slides&confId=116347