IT'S TEN TIMES HOTTER THAN THE SUN BUT ALSO THE COLDEST PLACE ON EARTH AND IT'S BEING BUILT DEEP IN THE FRENCH COUNTRYSIDE

Thomas Lane goes on the trail of the ITER - a £12.5bn multinational project that might just save the world...

There isn't a temperature gradient like this anywhere else in the universe," says Peter Sedgwick, design manager of consultant Atkins. Sedgwick is on the team responsible for planet earth's ultimate scientific and construction challenge. In the middle of the French countryside, they are building the world's first commercial-sized nuclear fusion reactor - a building that will simultaneously be the hottest and one of the coldest places on Earth. "The temperatures in the middle are 10 times hotter than the sun but 4m away this drops to -300°C," says Sedgwick.

Worth €13bn (£12.5bn), this is one of Europe's biggest engineering jobs and, if successful, will render discussions about the merits of renewable technologies, fossil fuels and conventional nuclear power obsolete.

Nuclear fusion is often described as the holy grail of energy production, and with good reason. Conventional nuclear power stations work by splitting uranium atoms, a process that releases huge amounts of energy. This process, called fission, has a multitude of disadvantages: it generates highly radioactive waste that takes thousands of years to decay, supplies of uranium are limited, and if safety systems fail the nuclear reaction can run out of control, leading to meltdown, as was so graphically demonstrated at Fukushima in Japan last year.

Nuclear fusion, on the other hand, has none of these disadvantages. It works by fusing two isotopes of hydrogen, one that is found in seawater and the other found in lithium, an abundant metal. Like fission this generates huge amounts of energy. Waste is far less of an issue: fusion generates helium, a harmless gas, and a tiny amount of mildly radioactive ash, which is dangerous for decades rather than millennia. Fusion is inherently safe as all the systems in the reactor are designed to maintain the reaction rather than to prevent it from running out of control. If anything goes wrong, the reaction will stop instantly.

As with most holy grails, it is not quite as simple as that. Getting these two isotopes to fuse requires temperatures of 150 million °C. The challenge is how to generate and maintain these temperatures and harness the energy given off by the fusion reaction using earthly materials and technology. Nobody in their right mind would blow €13bn on a full-sized nuclear fusion reactor if they didn't believe it was going to work.

Nuclear fusion has been achieved here on earth, in a facility called JET in the UK. Unfortunately, it required more energy to make it work than it produced, rendering it useless as a power source. This new project, called ITER (originally an acronym of International Thermonuclear Experimental Reactor), aims to rebalance this equation.

"The goal of this experiment is to put 50MW of power in to get 500MW out," explains Sedgwick. Atkins colleague, project director Christophe Junillon.

Atkins is part of a consortium called Engage, which is responsible for the design and procurement and supervision of the construction of the project. The job is made even more complex by the need to manage the seven countries funding the project (six box coevadl). Seven sections of the vacuum vessel inside the tokamak - the fusion reactor - will be made in Italy and two in Korea. This vessel will include 14km of welded joints which have to be impeccably done. Huge magnets are being made on site, but two will be made in Russia. All elements will have to conform to the French nuclear
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WHAT IS ITER

The International Thermonuclear Experimental Reactor, or ITER as it is now known, was born out of the Gernsheim era when Soviet president Mikhail Gorbachev and US president Ronald Reagan agreed to collaborate on the development of nuclear fusion. The project is a collaboration between six countries – China, India, Japan, Korea, Russia and the US - and the EU. The idea is that these countries contribute to the costs of ITER and jointly benefit from the knowledge.

All the countries want to be involved in delivering the project because of the commercial benefits that can arise. The chance to gain practical experience so they don’t contribute money, instead they contribute components. The project is being built at Cadarache which is also the home of French research facility, the Atomic Energy Commission. The European element of the project is being delivered by Fusion for Energy. The architect-engineer is a consortium called Engage and is responsible for the design, procurement and supervising the construction of the project. This is a joint venture between four companies: Akerk, Aksysy, Isolux and Empresas Agropagas.

HOW A NUCLEAR FUSION REACTOR WORKS

Nuclear fusion generates huge amounts of energy when two isotopes of hydrogen combine to form helium atoms. The two isotopes are deuterium, distilled from water, and tritium, generated inside the reactor from lithium.

Nuclear fusion requires temperatures of 150 million °C. There are several fusion technologies, but the most promising is the tokamak, a doughnut-shaped vacuum vessel where the reaction takes place. Inside the reactor, heat is generated using a superheated gas which becomes a plasma, a condition that occurs when electrons become separated from their nuclei. The plasma is sustained in space using a powerful magnetic field to prevent it from touching the walls of the vacuum vessel. High-energy particles are shot into the plasma and, together with the magnetic fields, this intensifies the heat.

When the deuterium and tritium fuse, a helium nucleus, energy and a neutron are produced. The neutron is unaffected by the magnetic field so it is absorbed by the walls of the tokamak, carrying 80% of the energy as it does so.

The tokamak is 13m in diameter and 11m high, and is double-skinned to allow cooling water to circulate and carry the heat away. It is ringed by coils which generate the magnetic field. Poloidal coils surround the vacuum vessel horizontally and toroidal coils vertically. Coils also run through the centre of the doughnut. These work most efficiently in superconducting mode, which necessitates cooling them to -259°C using cryogenic technology.

The tokamak will also feature remote handling technology, which will be used when the 440 segments making up the blanket that lines the walls of the vacuum vessel have to be replaced. This blanket is needed to shield the external elements of the tokamak from heat and slow down the neutrons generated by fusion.
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companies experienced in working in the nuclear sector: These include French, Spanish and German contractors. Ultimately there will be 39 buildings on the site, many of which are conventional in nature. Laurent Schneider, responsible for delivering the buildings on behalf of European clients, says that ITER is a huge, very expensive experiment with no guarantee that it will work. It won’t produce power, as the steam and turbine elements of a power station aren’t part of this project – they will come with later. It is unlikely nuclear fusion will take off commercially until at least 2050, so those conversations about nuclear fission, renewable and fossil fuels will continue - for now.

PETER SEDGWICK, ATKINS

THE PROJECT HAS MOVED IN THE LAST YEAR FROM A GLAM IN SOMEONE’S EYE TO SOMETHING REAL

A 15m deep hole has been blasted out of the French countryside for the tokamak building. The hole will act as an instant plenum for the tokamak, protecting the tokamak in the event of an earthquake. The reactor's final shape will be revealed when the internal elements of the tokamak are in place, with the blanket enclosing the core.

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