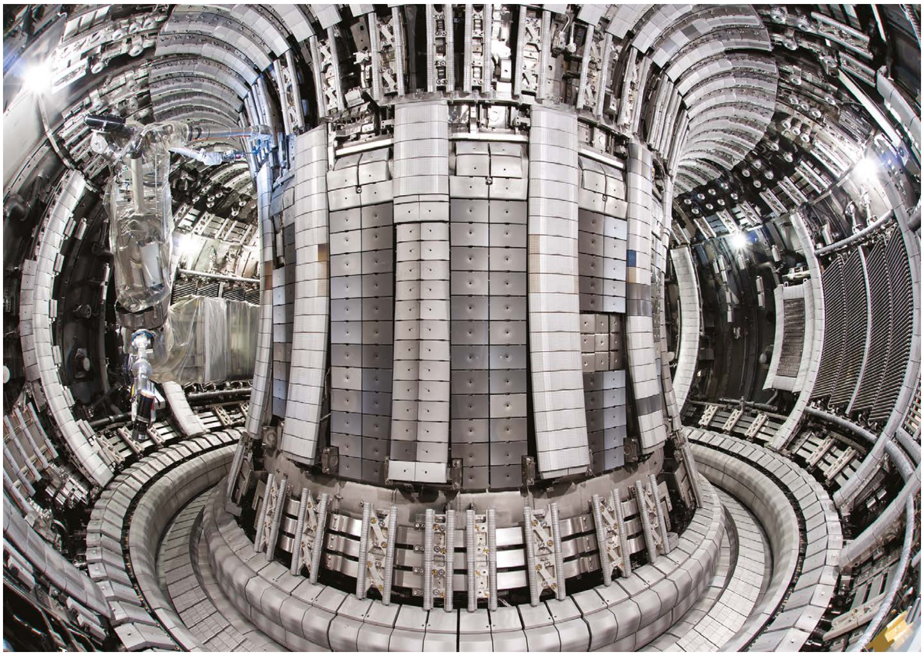

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The Joint European Torus tokamak reactor near Oxford, UK, hosted experiments with tritium.

NUCLEAR-FUSION REACTOR SMASHES ENERGY RECORD

The Joint European Torus has doubled the record for the amount of energy made from fusing atoms.

By Elizabeth Gibney

A 24-year-old nuclear-fusion record has crumbled. Scientists at the Joint European Torus (JET) near Oxford, UK, announced on 9 February that they had generated the highest sustained energy pulse ever created by fusing together atoms, more than doubling their own record from experiments performed in 1997.

"These landmark results have taken us a huge step closer to conquering one of the biggest scientific and engineering challenges of them all," said Ian Chapman, who leads the Culham Centre for Fusion Energy (CCFE), where JET is based, in a statement. The UK Atomic Energy Authority hosts JET, but its scientific programme is run by a European collaboration called EUROfusion.

If researchers can harness nuclear fusion – the process that powers the Sun – it promises to provide a near-limitless source of clean energy. But so far, no experiment has generated more energy than has been put in. JET's results do not change that, but they suggest that a follow-up fusion-reactor project that uses the same technology and fuel mixture – the ambitious US$22-billion ITER, scheduled to begin fusion experiments in 2025 – should eventually be able to reach this goal.

"JET really achieved what was predicted. The same modelling now says ITER will work," says fusion physicist Josefine Proll at Eindhoven University of Technology in the Netherlands, who works on a different kind of reactor called a stellarator. "It's a really, really good sign and I'm excited."

Two decades' work

The experiments – the culmination of almost two decades of work – are important for helping scientists to predict how ITER will behave, and will guide its operating settings, says Anne White, a plasma physicist at the Massachusetts Institute of Technology in Cambridge who works on tokamaks, reactors that, like JET, have a doughnut shape. "I am sure I am not alone in the fusion community in wanting to extend very hearty congratulations to the JET team."

JET and ITER use magnetic fields to confine plasma, a superheated gas of hydrogen isotopes, in the tokamak. Under heat and pressure, the isotopes fuse into helium, releasing energy as neutrons.

To break the energy record, JET used a fuel made of equal parts tritium and deuterium – the same mixture that will power ITER, which is being built in southern France. Tritium is a rare, radioactive isotope of hydrogen; when it fuses with the isotope deuterium, the reactions produce many more neutrons than do reactions between deuterium particles alone. That ramps up the energy output, but JET had to undergo more than two years of renovation to prepare the machine for the onslaught. Tritium was last used by a tokamak fusion experiment when JET set its previous record in 1997.

In an experiment on 21 December 2021, JET's tokamak produced 59 megajoules of energy over a fusion 'pulse' of 5 seconds – more than double the 21.7 megajoules released in 1997 over around 4 seconds. Although the 1997 experiment still retains the record for 'peak power', that spike lasted for only a fraction of a second, and the experiment's average power was less than half that of the latest test, says Fernanda Rimini, a plasma scientist at the CCFE who oversaw last year's experimental campaign. The improvement took 20 years of experimental optimization, as well as hardware upgrades that included replacing the tokamak's inner wall to waste less fuel, she says.

Power ratio

Producing the energy over a number of seconds is essential for understanding the heating, cooling and movement happening inside the plasma that will be crucial to run ITER, says Rimini.

Five seconds "is a big deal", adds Proll. "It is really, really impressive."

Last year, the US Department of Energy's National Ignition Facility set a different fusion record: it used laser technology to produce the highest recorded fusion power output relative to power in, a value called *Q*, where 1 would be generating as much power as is put in. The facility achieved a *Q* of 0.7 – a landmark for laser fusion that beat JET's 1997 record. But the event was short-lived, producing just 1.3 megajoules over less than 4-billionths of a second.

JET's latest experiment sustained a *Q* of 0.33 for 5 seconds, says Rimini. JET is a scaled-down version of ITER, at one-tenth of the volume – a bathtub compared with a swimming pool, says Proll. It loses heat more easily than ITER, so it was never expected to hit breakeven. If engineers applied the same conditions and physics approach to ITER as to JET, she says, it would probably reach its goal of a *Q* of 10, producing ten times the energy put in.

Fusion researchers are far from having all the answers. A remaining challenge, for example, is dealing with the heat created in the exhaust region of the ITER reactor. ITER's exhaust will have a bigger area than JET's, but the increase will not be in proportion to the surge in power it will have to deal with. Research is under way to work out which design should best withstand the heat, but researchers are not there yet, says Proll.