Thorium reactors could rescue nuclear power

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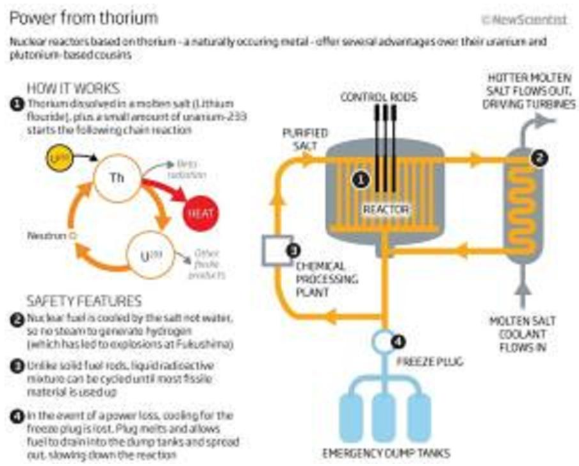

Power from thorium

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"IT IS not difficult to conceive of an entire planet powered by thorium," wrote Kirk Sorensen on his blog Energy From Thorium in 2006. Some would contest this bold claim, but given the crisis at the Fukushima Daiichi nuclear power plant in Japan, the energy source Sorensen advocates has been thrust into the spotlight.

Sorenson and others propose building reactors that use a naturally occurring element called thorium as the main starting material, instead of uranium or plutonium. Though the technology is far from fully developed and very different to conventional plants based on solid uranium and plutonium fuel, advocates say it would be immune to the problems that have plagued the Fukushima reactors and should produce less radioactive waste than conventional reactors.

"It has some really compelling safety advantages," says Sorensen, who is now chief nuclear technologist at the firm Teledyne Brown Engineering in Huntsville, Alabama.

He is not alone in his passion for thorium, which is globally much more abundant than uranium-235, the fuel used in conventional uranium reactors.

For some, nuclear energy, in particular thorium, is the best way to fight climate change. "We have got to stop using carbon fuels," says Roger Barlow, a particle physicist at the University of Manchester, UK. "I don't think unfortunately that renewables will provide the energy we need."

Still, thorium is just one of many possible ways of improving the safety of nuclear power plants (see "How newer reactors would have survived Fukushima"). Thorium reactors also present unique challenges that must be overcome before a working version could become reality. And that's without considering the cost of a switchover.

At the heart of a liquid fluoride thorium reactor (LFTR) is a chamber filled with thorium dissolved in a molten salt such as lithium fluoride at several hundred degrees Celsius. Thorium itself is barely radioactive, so a small amount of uranium-233 is added to kick-start nuclear reactions. Like U-235, it is radioactive and so fissions, releasing heat as well as neutrons. These hit thorium atoms, transforming them into more U-233 and producing heat in the process. The U-233 in turn fissions to produce more neutrons (see diagram). "It is a continual process of turning thorium into U-233, burning it up and generating new U-233," says Sorensen.

The fuel cools as it passes through a heat exchanger containing more molten salt, and this heated salt can then be used to drive turbines and generate electricity.

Without water as a coolant, there is a much lower risk of explosions. At Fukushima, these were caused by the build-up of steam and the generation of hydrogen by the breakdown of water.

A liquid fuel also reduces the volume of radioactive waste. In conventional uranium reactors, the solid fuel rods have to be removed from the core long before their radioactive waste products have decayed and the uranium fuel has been used up. That's because too much radiation makes the fuel rods swell and crack, allowing radiation to leak out.

By contrast, the fuel in a liquid reactor is unaffected by radiation and so can continue to be used until virtually all its radioactive components have undergone further reactions, or decayed into non-radioactive waste products.

Another advantage is that, unlike conventional solid fuel rods, fluoride salts are not flammable. If solid rods catch fire they release plumes of radioactive smoke.

The difficulty with fluoride salts, though, is that they are highly corrosive, so special materials are needed to contain them. An experimental molten salt reactor that ran from 1965 to 1969 at Oak Ridge National Laboratory in Tennessee used a corrosion-resistent nickel-molybdenum alloy called Hastelloy N as a container material. But even this had degraded by the end of the project.

Also, athough LFTRs would burn up most of the waste they produce, they would not eliminate every trace. Safe storage for some long-lived radioactive material would still be needed.

Pavel Tsvetkov, a nuclear engineer at Texas A&M University in College Station, points out that many of the claimed safety advantages of LFTRs must still be proved in more detailed studies. "Safety research is yet to be done," he says.

In December 2010, Europe's atomic energy agency Euratom committed to funding a €1 million study called EVOL. It will start with experiments and calculations involving liquid fluoride salts. "We have to first prove it's possible to handle that [material]," says Elsa Merle-Lucotte of the Laboratory of Subatomic Physics and Cosmology in Grenoble, France, one of the institutions involved in the project.

The aim of the study, which will run until November 2013, is to lay the groundwork needed before an LFTR can be designed. The project's participants then hope to win funding for a prototype. "Our dream is to build a demonstrator," says Merle-Lucotte.

Other countries are working on thorium energy, too. In January, the Chinese Academy of Sciences announced funding to develop a molten salt thorium reactor as part of a broader plan for science and technology development called Innovation 2020.

India has long experimented with thorium fuel, though in solid form. Though this lacks many of the advantages of the LFTR, India is keen to find ways to use thorium in conventional nuclear reactors as the country has abundant deposits of the metal and a scarcity of uranium.

Sorensen says he thinks the benefits of LFTRs will spur technology start-ups to invest in developing it, even if the established nuclear companies are reluctant because it is so different from what they know.

"When you look at the individual technologies that go into a fluoride reactor they're totally different to what we use today," he says. "I think it's going to be new entrepreneurial companies that make this happen."

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Back to article