The future of nuclear energy

Cheap electricity, no plutonium and no meltdowns. This is what the thorium molten salt reactor is promising. TU Delft has been given a grant to research this almost utopian reactor.

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'Just tell me: what do we have to do to convince people that this is a different type of nuclear energy, that this technology has a real future? Whenever I mention nuclear energy in Parliament, people immediately think of Fukushima.'

This plea came from the floor during a symposium on thorium molten salt reactors on 17 April. It came from André Bosman, MP for the VVD and advocate of the thorium reactor. So how can you generate enthusiasm for nuclear energy among politicians and voters in the wake of the Fukushima nuclear disaster?

'Your task is much more difficult than mine as a researcher', replied American Kirk Sorensen from the stage. Sorensen has a healthy sense of irony and is one of the keenest supporters of thorium reactors. In 2005, when working for NASA, he came up with the idea of designing an energy plant for the moon. He decided that a thorium-based reactor would be the best option. But, he thought, this type of reactor is also perfect for Earth. The American hopes that his own start-up company, Flibe Energy, will be the first to bring these reactors onto the market. But he will have to work fast. During the symposium, Canadian Dave Leblanc explained that his company, Terrestrial Energy, hoped to have a fully operational reactor by 2024. And then there's Leslie Dewan, the 29-year-old alumnus from Massachusetts Institute of Technology, who launched the company Transatomic Power four years ago and acquired several million in funding from investers to build a thorium reactor.

Pioneers

Startups that think uranium is a thing of the past are springing up like mushrooms, particularly in the United States, Canada, England, Scandinavia and Germany. In their eyes, thorium is the future. A handful of these pioneers unveiled their plans at the symposium.

Researchers from Delft were among those who took the stage. Last month, it was announced that scientists from TU Delft will be heading a European thorium research project worth €3.5 million. The partners include research institutes from Germany, France, Italy and Switzerland – among others.

Like the start-up companies mentioned above, this European project will focus specifically on the thorium molten salt reactor or MSR. In this type of reactor, the fuel (thorium) is dissolved in molten salt of lithium fluoride or beryllium fluoride, which also serves as a coolant. The pressure inside the reactor is low, making the risk of explosion negligible. If a leak occurs, the fuel flows out of the reactor along with the coolant and the reactions inside the reactor cease. The salt solution clots and all the radioactive material is trapped in the salt. At least that's the theory.

Grand dream

Dr Jan Leen Kloosterman from the Reactor Institute Delft initiated the project and organised the symposium. He is keen to add to his list of advantages of the Thorium MSR.

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'Thorium is an extremely common natural resource on Earth. It is four times more plentiful than uranium. What's more, we only use one percent of the uranium found on Earth. So a thorium reactor can generate hundreds of times more energy from thorium than we currently generate from uranium. There are beaches in India where a kilo of sand contains fifty grams of thorium. This will generate as much electricity as 100,000 litres of petrol. My grand dream is to extract this energy from thorium.'

'But the best part is that a thorium MSR does not produce long-lived radioactive waste – and no plutonium. It is also an efficient way of clearing existing waste out of nuclear energy plants and nuclear weapons and transforming it into energy.' (see box)

Molten salt reactor technology is nothing new. Its inventor, Alvin Weinberg, had a working MSR at the Oak Ridge National Laboratory in the United States from 1965 to 1969. Although the Weinberg reactor seemed to be a promising development, the project was stopped. One of the explanations given was that countries needed nuclear reactors that ran on uranium to produce the huge amounts of plutonium required to make nuclear bombs.

Lifespan

So although the thorium reactor is a development an earlier invention, a huge amount of research is still needed. Too little is known about the lifespan of the materials used in the reactor, for example. And the chemistry of the salt must be scrutinised more closely. Prof. Jilt Sietsma (3mE), materials researcher and speaker at the symposium, was crystal clear about the extent of the research remit. 'Just look at this devastation', he said, pointing to a photo of a pockmarked metal sheet made from a nickel alloy. Nickel is one of the materials that may well be used for the pipe network in the reactor. 'It has been totally blitzed by radioactive radiation.'

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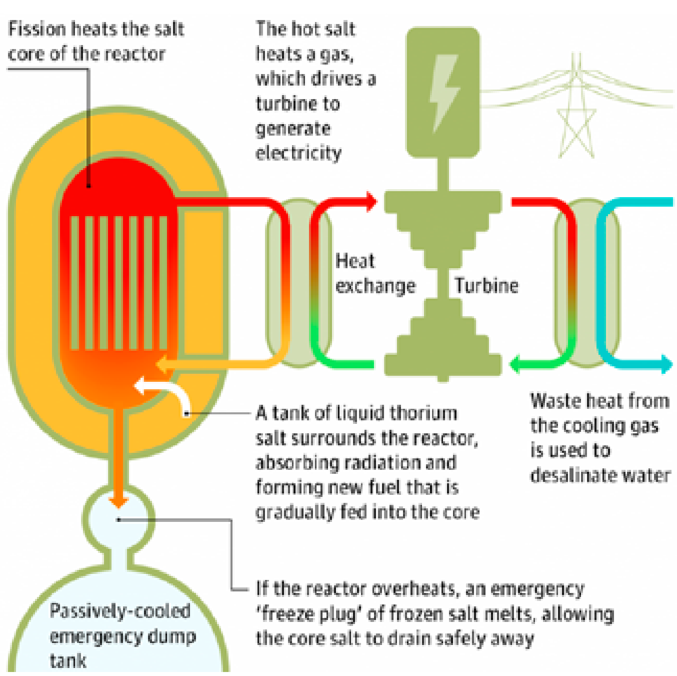
According to the materials researcher, the inside of a thorium MSR is about as dangerous as it gets in this respect. 'The material is subjected to very high temperatures. The salt is 700 degrees Celsius, which is half the melting temperature for nickel. The lithium fluoride causes corrosion and then there's the continual bombardment from radioactive particles. It would be difficult to imagine worse conditions.'

Having said this, Sietsma is by no means sceptical about thorium. 'I think we'll be able to solve the material problems as long as we do enough research.' To Sietsma's mind, the thorium reactor could bridge the gap between sustainable and fossil energy. 'Solar panels and wind turbines are great, but progress in these fields is too slow. And the other alternative, nuclear fusion, is still too far away.'

A billion euros

Sietsma and several colleagues from TU Delft went to the Energy Committee of the Dutch House of Representatives a few days before the symposium to promote thorium research. The few million euros being offered by the European Union is merely a drop in the ocean, according to the scientists from Delft. 'We need a billion euros over a period of 20 years,' says Sietsma. As yet, only Asia is seriously investing in MSR technology, say the researchers. China started a research programme involving hundreds of researchers a few years ago. In 2012, Kloosterman told Delta: 'The next generation of thorium reactors will come from China unless Europe really gets a move on.'

Thorium reactor



What's the difference?

In existing light water reactors (LWR), the nuclear fuel consists of uranium-dioxide tablets enclosed in an elongated, gas-proof metal casing made of zirconium alloy. These fuel rods are bundled into nuclear fuel elements, several hundred of which together form the reactor core.
The waste products from nuclear fission are radioactive and generate heat, even when the nuclear fuel reaction is halted. If this decay heat is not removed – for example, in the event of significant damage to the cooling system after an earthquake, as was the case at Fukushima – the fuel rods can overheat. Ultimately, the fuel rods themselves can melt, which releases radioactive substances.
In addition, this type of reactor only uses one percent of the available uranium and irradiating the non-fissile type of uranium in the nuclear fuel elements produces dangerous plutonium. Although this plutonium can certainly be recycled, full recycling requires a new type of nuclear plant (a sodium-cooled fast breeder reactor), which does not yet exist. If it is developed, it will carry a small risk of a major incident.
The molten salt reactor does not have these problems. Since the fuel is dissolved in molten salt, there is no temperature difference between fuel and cooling. The nuclear reaction stops automatically if the temperature becomes too high. There is therefore no danger of over-heating, volatile nitrogen cannot be formed and no meltdown can occur.
However, the Delft researchers think that the best thing about the MSR is that all the fuel undergoes fission and is converted into electricity. This is not only true of thorium, but also of the hazardous nuclear waste that has already been produced. This can be gradually fired in the reactor.
The remaining nuclear products will have lost practically all their radioactivity within 300 years, which simplifies the geological storage process. And last but not least, the residual waste would be unsuitable for producing nuclear weapons.

The behaviour of fluoride salt is another major point of concern within the European project. The initiator of this line of research is Prof. Rudy Konings, professor of nuclear fuel cycle chemistry (Applied Sciences), who also works for the Institute for Transuranium Elements in Karlsruhe. He explained that an experiment involving irradiating fluoride salt is due to take place at the NRG High Flux Reactor in Petten later this year.
Konings hopes to discover whether the theory that radioactive material (including caesium and iodine) becomes trapped in the salt in the event of a leak is really true.

Opponents

Although a number of people voiced reservations during the symposium, most people seemed to embrace the general concept of the thorium molten salt reactor. It was largely preaching to the converted, but there are still plenty of fervent opponents in the world.
One of them is Arjun Makhijani, chair of the Institute for Energy and Environmental Research, an American think-tank and lobby club opposed to nuclear energy. Makhijani disputes the notion that thorium reactors are safe from a terrorism point of view because they do not produce plutonium. According to him, the reactors produce a substance that is much more dangerous than plutonium: uranium-233.
A thorium MSR is fuelled by thorium. As this element is non-fissile, it must first undergo a neutron bombardment in the reactor to turn it into fissile uranium-233. A terrorist or rogue state could have a field day simply by draining salt from the reactor and extracting the uranium-233. It is even easier to develop dirty bombs with uranium-233 than plutonium, argues Makhijani on his website.
This actually increases the risk, he says, because draining the salt will be a standard procedure with MSR reactors. The salt needs to be cleansed in order to keep the nuclear reaction going. Small amounts of the salt mixture flow through a processing tank to remove nuclear fuels and other unwanted by-products.
According to Jan Leen Kloosterman, extraction of uranium-233 does not pose a huge threat. Or maybe it does, depending on your point of view. He believes that we shouldn't be too concerned about bombs. 'The salt mixture does also contain uranium-232, which is a highly dangerous substance. It emits enormous doses of gamma radiation, which would very quickly do away with the terrorists.'

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