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ENERGY

Supercritical CO2, molten salt could stop a nuclear meltdown before it begins

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A glass scale model of a nuclear power plant in Essen, Germany, will help scientists test ways to reduce the risk of meltdowns. Image courtesy of sCO2-HeRo

Fukushima, Chernobyl, Three Mile Island - all three nuclear disasters were caused by human error, in one form or another. Now researchers are working on ways to ensure nuclear power plants remain safe – by making safety systems that can operate automatically.

A nuclear meltdown happens when the reactor's residual power exceeds the heat that can be removed by the cooling systems. The core - where the nuclear reactions take place - can't withstand the rising temperature and begins to melt, allowing radioactive materials to possibly escape into the environment.

Over the last few decades, public fears in some countries have prevented more nuclear power from entering the grid. However, if the threat of a meltdown can be removed, some scientists think we should reconsider tapping into this carbon-free source of energy.

They are working towards different ways to eliminate the risk of nuclear meltdowns, with automatic methods such as a heat removal system using so-called supercritical CO2, a state where the chemical has properties of both a gas and a liquid, and the use of molten salt.

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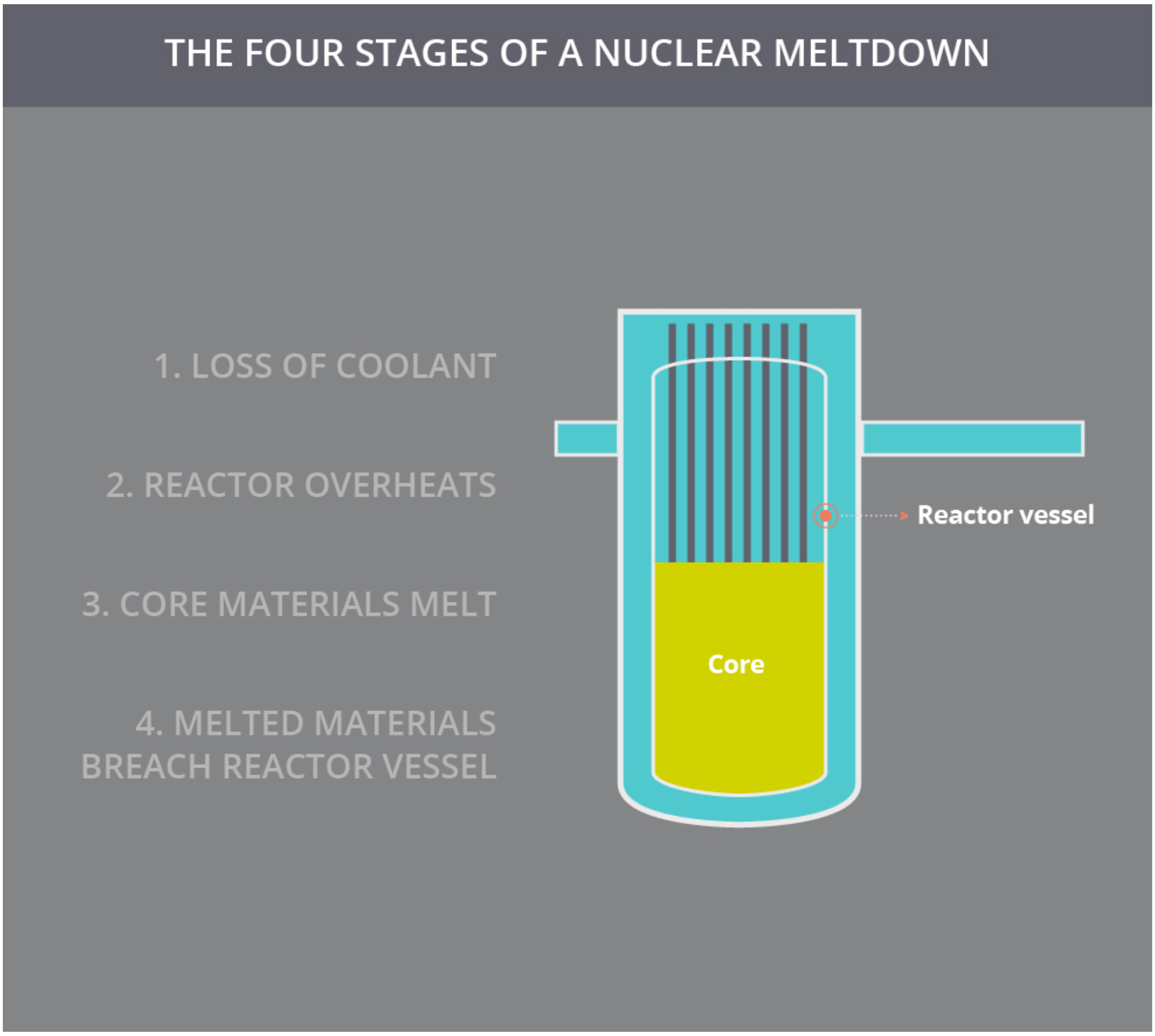
The supercritical CO2 approach effectively removes heat build-up from a core without the requirement of external power sources, meaning it could work if the power is somehow cut, for example, during a natural disaster.

'By removing the heat, it prevents a potential core meltdown and buys time to react,' said Professor Dieter Brillert from the University of Duisburg-Essen in Germany, who is the project coordinator of sCO2-HeRo, an EU-funded project developing the technology.

In theory, the system designed by sCO2-HeRo would stop a meltdown before it begins, opening a window for power plant operators to identify, and address, the potential overheating of the core by, for example, alternative mobile cooling systems.



When all safety systems fail, loss of coolant in a reactor will quickly build up heat and melt the radioactive materials.

Its strength rests in the fact that supercritical CO2 is able to transport huge amounts of heat in a low-cost, non-toxic and non-flammable way. In a reactor's case, it can rapidly remove heat from the core's surface and release it through steam.

‘The system kicks in automatically and no operator action is required,’ said Prof. Brillert.

Professor Jörg Starflinger, a nuclear energy expert from the University of Stuttgart in Germany, is also working on sC02-HeRo and says that its compact system means it can ’be tailored for old power plants’ and ‘new ones too’.

Coolant

Another technology that could prevent a meltdown is a Molten Salt Fast Reactor (MSFR), which uses molten salt combined with thorium and uranium to simultaneously act as a fuel and coolant.

In MSFR systems, a ‘meltdown has no meaning’, according to Professor Jan Leen Kloosterman, a nuclear energy expert from Delft University of Technology, the Netherlands.

> 'Many people see this technology as a kind of game changer.'
>
> *Professor Jan Leen Kloosterman, Delft University of Technology, the Netherlands*

‘Because the fuel is a fluid, if it heats up too much it will expand and the nuclear fission reactions die out – without intervention of operators or the control system.’

In exceptional circumstances, a freeze plug, which is also made of salt and melts if the molten fuel gets too hot, allows the fluid to escape into a special container. The plug would also break in an event of an earthquake, preventing any sort of Fukushima-like accidents.

‘The risk that nuclides (radioactive atoms) can be distributed into the environment is very small in MSFR,’ said Prof. Kloosterman, who is the project coordinator of SAMOFAR which is looking to develop MSFR using thorium as a fuel.

‘Thorium is a lighter element so you produce about one thousand times less of the long-lasting actinides (such as) plutonium. The remaining waste only requires a storage time of 500 to 1 000 years instead of 200 000 years.’

SAMOFAR is developing a safety methodology and is testing safety devices for the MSFR experimentally and with numerical models. It is also measuring the properties of molten salts. All results have so far strengthened the optimism of MSFR as an inherently safe reactor.

‘Many people see this technology as a kind of gamechanger, it could really change public opinion,’ said Prof. Kloosterman, but admits we won’t see any MSFR reactors ‘until at least 2050’.

Neo-nuclear

China is expected to build between 40 and 60 new power plants by 2050. In Europe, for the first time in over 20 years, there are plans for new plants in France, Finland and UK while two more Russian-designed reactors are planned in Hungary.

It appears nuclear energy is here to stay - making safety in power plants more important than ever.

Florian Fichot, from the French Institute for Radiological Protection and Nuclear Safety, said: ‘What we learned from Fukushima, Three Mile Island and Chernobyl, is the risk (of a meltdown) was underestimated at the beginning.

A preventative solution developed in new plants is In-Vessel Melt Retention (IVMR), which intends to stop the progression of a meltdown by automatically flooding the reactor pit with water if the system detects a rising temperature in the core, reducing the risk of human oversight.

‘IVMR strategy will be implemented in some of the new reactors, in particular in new Chinese designs for which IVMR is the preferred strategy,’ said Fichot.

Similar to sC02-HeRo and SAMOFAR, this would increase the level of safety at nuclear power plants. But at the moment IVMR can only prevent meltdowns in reactors with a power capacity below 600 megawatt electric (MWe). Many reactors run at 1 000 MWe and higher, and for them the possibility of IVMR preventing the progression of nuclear meltdowns can’t be guaranteed.

Fichot is the project coordinator of an EU-funded study, also called IVMR, investigating the IVMR strategy for higher power reactors.

'We are trying to identify the maximum level of power in a plant for which this strategy can be implemented.’

IVMR can help reduce the risk of a nuclear meltdown, but if it still occurs it won’t completely eliminate the risk of contaminating the environment. It would have to be combined with other safety measures to maximise the level of safety.

Responsibility would then rest with utility companies who implement these safety measures. However, this can be difficult in light of the very large investments needed to build a nuclear power plant, as well as for the general costs during its lifespan.

Despite this, utility companies want to build reactors as safely as possible, as this would help sway public opinion, but to do so they need to have a better picture of the overall costs.

‘If there is a clear cost of electricity production, and also transparency on safety, then public acceptance for nuclear energy may be easier,’ said Fichot.

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sCO2-HeRo

SAMOFAR

IVMR