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CURRENT INNOVATIVE TRENDS IN NUCLEAR REACTORS DESIGN AND THEIR POTENTIAL ROLE IN INCREASING THE WORLD SHARE OF NUCLEAR POWER

Introduction

Nuclear technology utilizes the energy released from nuclear fission or the split of atoms of certain isotopes. The first developed nuclear technology was in the 1940s, during the Second World War. Research was initially focused on weapons production; however, In the 1950s the attention was turned into the peaceful uses of nuclear energy for power generation. Currently, about 440 power reactors are in use, providing around 10% of the world's electricity (figure 1) [1], making Nuclear energy as the world's second largest source of low-carbon power.

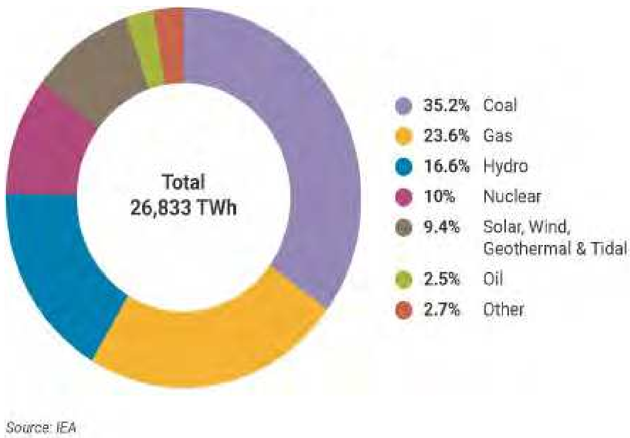

Fig. 1. World electricity production [1]

The Fukushima Daiichi Nuclear Accident

At the beginnings of the 2000s, amid growing awareness to the links between climate change and the energy related greenhouse emissions, the idea of ‘nuclear renaissance’ has became popular. Policy makers and scientists identified nuclear power as a potential key player in the clean energy transition. However, the Fukushima Daiichi Nuclear Power Plants accident in 2011 had serious consequences that disrupted this trend. In the aftermath of this accident, the international community turned its attention to strengthening nuclear safety, while many countries chose to phase out nuclear power. In Japan, with public confidence in nuclear power at its lowest levels, the Japanese authorities had to decide on suspending the operations at 46 of the country's 50 total operating nuclear power reactors. Meanwhile, Germany decided to entirely phase out nuclear power by 2022, less than three months later after the accident, following public pressures. Belgium also confirmed its plans to phase out nuclear Energy by 2025 [2].

Rebuilding Confidence – Innovative Designs

The road back to nuclear power is being built on actions taken at the international levels to distribute factual information on the Fukushima Daiichi accident actual impact, and on strengthen nuclear safety further, combined with an ongoing effort towards an innovative fuel and reactors designs with an anticipated outstanding performance.

Russia’s deployment of the BN-800 fast reactor in 2016, a technology that has the potential to reduce nuclear waste, underlined the potential long-term nuclear energy’s sustainability. Meanwhile, the Accident Tolerant Fuel concept has emerged, with many proposed advanced fuel and claddings concepts been actively developed and tested worldwide. In the United States, the U.S. Department of Energy is actively engaging with industry to develop new fuels possessing an enhanced accident tolerance features within a short-term timeframes. These nuclear fuels utilize new materials with ability to reduce hydrogen buildup, improved retention of fission gases and products. They are structurally possess more irradiation resistance, corrosion resistant, and can withstand high temperatures and harsh reactor core environment. This proposed accident tolerant fuels are expected to function more efficiently inside the nuclear reactor core and to be able to last longer. This would potentially extend refueling time from 1.5 years to 2 years or even more and use less fuel by nearly 30%. This would indicate reduced fuel costs and less waste over the operating life of the nuclear reactor.

The leading French company Framatome, Westinghouse and GE’s Global Nuclear Fuel are currently engaged in testing their developed accident tolerant fuels. In collaboration with national laboratories and the government, the three companies look forward to commercializing and deploying their nuclear fuel concepts by 2025.

Meanwhile, international efforts are being accelerated to develop the small modular reactors (SMRs), including the first SMRs deployment. Currently, these SMRs are being seen as one of the most promising emerging nuclear technologies. In contrast to the existing reactors, these proposed SMRs designs are generally simpler and extensively rely on the inherent and the passive safety features. Hence, they are likely requiring lesser up-front costs as well as providing more flexibility to the smaller grids. It also could be integrated with renewable as well as the non-electric applications like water desalination and hydrogen production. These new innovative nuclear reactors designs are expected to generate generally less nuclear waste and even operate on the recycled spent nuclear fuel (closed cycle).

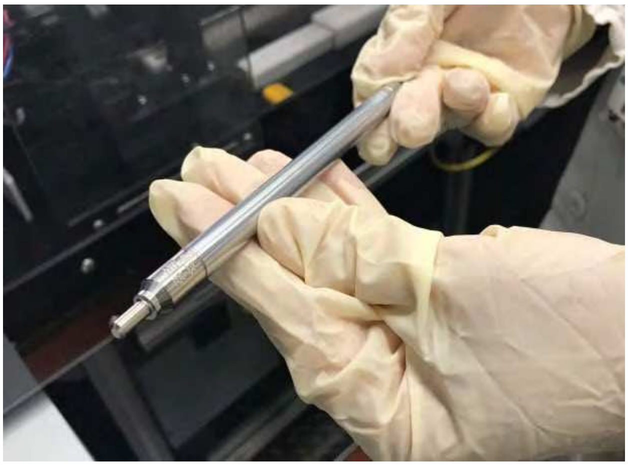

Fig. 2. Test fuel pins of the new chromium coated Zircaloy with new fuel pellets welded inside, developed by Framatome [3]

Conclusions

Years following the accident at Fukushima Daiichi, and as the Paris Agreement on climate change entered into force, the number of countries looking to nuclear power as one of the means of addressing climate change are increasing. Momentum has begun to assemble behind the notion that nuclear power potentially has a major role to play with regard to climate change mitigation and sustainable development. These countries also started to look at the potential role that nuclear power could play in improving energy security, lessen the effects of the volatile prices of fuel and improve the competitiveness of their economies. In its annual projections of 2020, the international atomic energy agency said that nuclear generation capacity may double by 2050 or might decline to slightly lower than the current levels. Commitments that have been made under the Paris climate change agreement and other international initiatives can support the further development of nuclear power, nevertheless, that will require energy policies establishments and market designs to simplify investments in distributed, low-carbon technologies. Hence, the current proposed innovative reactor and fuel designs would hugely contribute in advancing this development if proved its competitiveness and commercialized.

REFERENCES

1. World nuclear association, “Nuclear Power in the World Today” March 2023. https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

2. Henri Paillere and Jeffrey Donovan, "Nuclear Power 10 Years after Fukushima: The Long Road Back" IAEA Department of Nuclear Energy, 2021, https://www.iaea.org/newscenter/news/nuclear-power-10-years-after-fukushima-the-long-road-back"
3. New Accident Tolerant Fuel by Framatome Being Tested at Idaho National Laboratory "U.S. Office of Nuclear Energy. https://www.energy.gov/ne/articles/new-accident-tolerant-fuel-framatome-being-tested-idaho-national-laboratory

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COOLING SYSTEM OF THE BIOLOGICAL PROTECTION OF THE IRT-T REACTOR

Introduction

The IAEA precaution norms establish basic safety principles, provisions, and measures to curb irradiation to human beings and the discharge of radioactive material to the surroundings. They also reduce the possibility of incidents that could result to inability to manage the atomic reactor, or any activity that results to the release of radioactive substances. This includes nuclear sites, the use of radiation sources, the shipping radioactive materials, and the control of radioactive waste, among other locations and activities that include a danger from radiation [1]. Biological protection is designed to create a radiation environment at workplaces, in the reactor rooms in accordance with radiation safety standards. According to fundamental safety principles, the best possible level of safety must be provided through optimizing protection. [2]. The biological protection of the reactor includes the pool water, the concrete mass of the reactor pool protection, the gates of the horizontal experimental channels, and the protective boxes of the reactor process equipment [3]. During operation of the reactor, a lot of heat is released in the reactor vessel. With these conditions, the biological protection of the reactor absorbs heat. Therefore, there is a need to cool the protection system.