Role of the ADS from the perspective of the International Thorium Energy Committee iThEC

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Abstract

The international Thorium Energy Committee in Geneva has been established to investigate the ADS fuelled by thorium. The committee, formed by prominent members of the scientific community of CERN under the auspices of Carlo Rubbia, the original inventor of the ADS concept, also comprises business leaders and members acquainted with public relations in an effort aimed at broadening the appeal of the ADS concept.

Nuclear policy today in Europe and more particularly in Switzerland has reached a point where crucial decisions must be made, which affect the security of the electricity supply, the fulfillment of commitments to the Kyoto Protocol to combat climate change while addressing public concerns following the Fukushima accident. Nuclear power has its advantages, yet the perennial problem of what to do with the waste, the perceived risks due to criticality have long been a thorn in the side of nuclear power, preventing it from taking its place as a core technology of the 21st century and beyond. The iThEC committee members are actively pursuing the goal of reversing the current negative trends in Europe by supporting thorium ADS technology by actively engaging in the scientific, political and business leadership.

Introduction

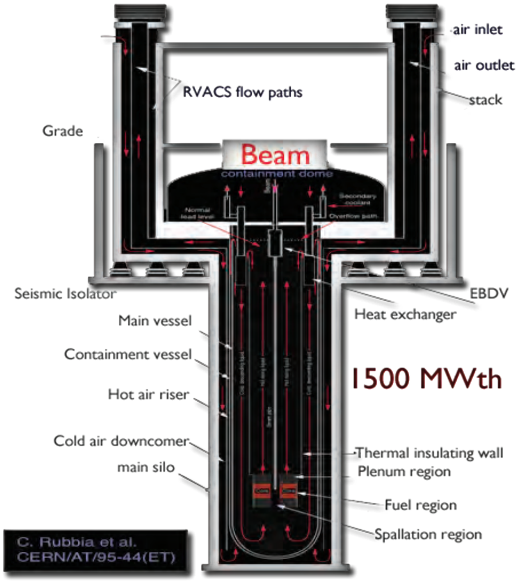
In October 2013, the International Thorium Energy Committee (iThEC) created in 2012 as a non-profit organisation, held at CERN an international conference on a new form of nuclear energy production based on thorium. This committee aims to contribute to the development of a sustainable solution to the world energy problem by promoting the construction of a prototype thorium reactor controlled by a particle accelerator system called an ADS or Accelerator-driven System as proposed by the Nobel laureate in physics; Carlo Rubbia at CERN [1] [2], (see Figure 1).

The benefits of such a proposal can be summarised as follows:

- Demonstrate on an industrial scale that much of the volume and the lifetime of existing nuclear waste can be eliminated, thus reducing the risk of deep disposal, along with the costs and fears that it generates.
- Demonstrate that it is possible to develop a new global energy concept, sufficient to contribute to the harmonious development of the planet without compromising its fragile ecological balance.
- Preserve local know-how and independence in the nuclear field to ensure an effective direct control of existing nuclear power plants including their future

dismantling. The permanence of nuclear expertise is also vital for the future of nuclear medicine.

Figure 1. Carlo Rubbia's energy amplifier concept [1] [2]



The energy problem is a major challenge for our civilisation and the manner in which it will be dealt with, will largely determine the fate of humanity. World energy consumption should be tripled in order to provide the world population at the end of the 21st century with a consumption level comparable to that of today's European population, even when assuming increased energy efficiency.

It would therefore seem unwise not to undertake a systematic piece of research in all modes of energy production, as otherwise the world will be deprived of innovative and sustainable solutions. In some countries such as Switzerland, the parliament decided that the country could manage without its current nuclear power plants until 2050, but prudently also reaffirmed that it would continue to encourage research and development in this field.

Nuclear waste management in Switzerland

Opting out of nuclear energy implies decommissioning existing nuclear power plants but it also still entails dealing with the waste that these plants have produced throughout their useful operational lives as well as finding other realistic environmentally acceptable energy sources. Today, the only considered option for the waste is deep burial, which is a controversial political subject. Projections from the Swiss repository authority NAGRA (Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle) of the cost of burial have given rise to concerns in economic circles. It is significant that a recent vote calling for a faster provision of funds to the nuclear decommissioning fund over 40 years instead of 50 years was overwhelmingly approved by the Swiss parliament. The nuclear decommissioning fund is to accrue 20 billion Swiss Francs in total, of which 13 billion is marked for financing deep burial.

Thorium-ADS

In this context, iThEC undertook to promote research and development in the field of nuclear energy based on the use of thorium. Current nuclear power systems do not offer the best possible use of nuclear fission. Therefore, it seems natural to question whether it would be possible to conceive other methods that would be more acceptable to society. A number of nuclear experts believe that it is indeed possible to develop new nuclear systems without the drawbacks of existing plants, such as accidents, waste management and military proliferation. The work of Nobel-prize laureate Carlo Rubbia has shown that there are many more efficient ways due to the effective coupling of particle accelerators technology with subcritical nuclear reactors and using thorium, a thorium-ADS.

The use of thorium in a subcritical fast reactor configuration driven by an accelerator (ADS) and cooled by natural convection of liquid metal offers significant advantages in terms of resource abundance, security, non-proliferation and drastic reduction of existing and future waste.

High intrinsic safety is ensured by the possibility of immediate shutdown due to the accelerator, while maintaining cooling liquid metals such as lead at a temperature well below boiling. This chemically inert coolant removes the danger of the formation and explosion of hydrogen like in Fukushima, and is naturally safer than liquid sodium envisaged in Gen-IV reactors. Furthermore, the natural circulation is independent of pumps and does not require a power supply.

The risk of military proliferation is greatly reduced because the plutonium production is negligible. The main element is the fissile isotope ^{233}U (produced by neutron capture by thorium: Figure 3), but it is present in an isotopic mixture unfit for military operational use.

The production of long-lived waste (plutonium and minor actinides) is greatly reduced compared to uranium-based fuel. With a thorium-ADS, it is possible to eliminate much of the waste resulting from the operation of existing uranium plants (see Figures 2, 3). This reduces the size and complexity of, or may indeed eliminate the need for long-term nuclear waste storage sites, which is an important issue.

Figure 2. Reduction in activity through transmutation of long-lived nuclear waste [1] [2]

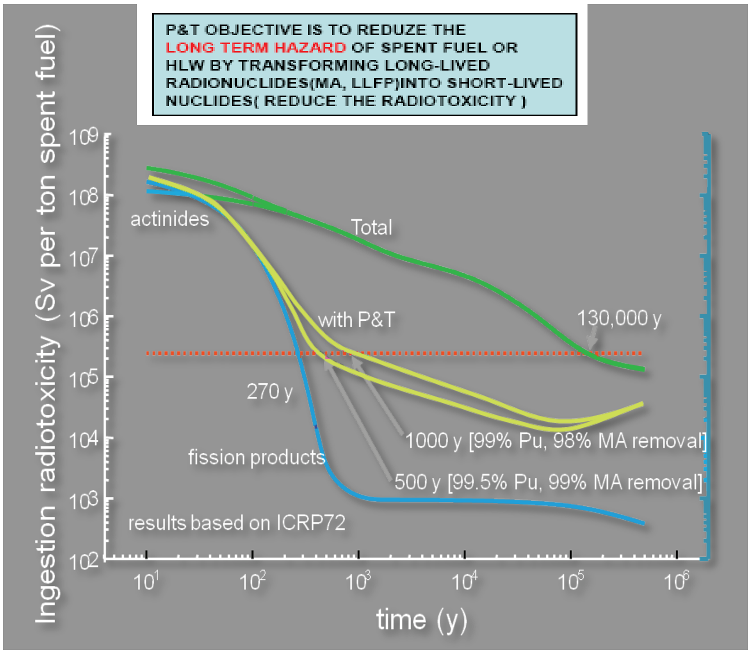
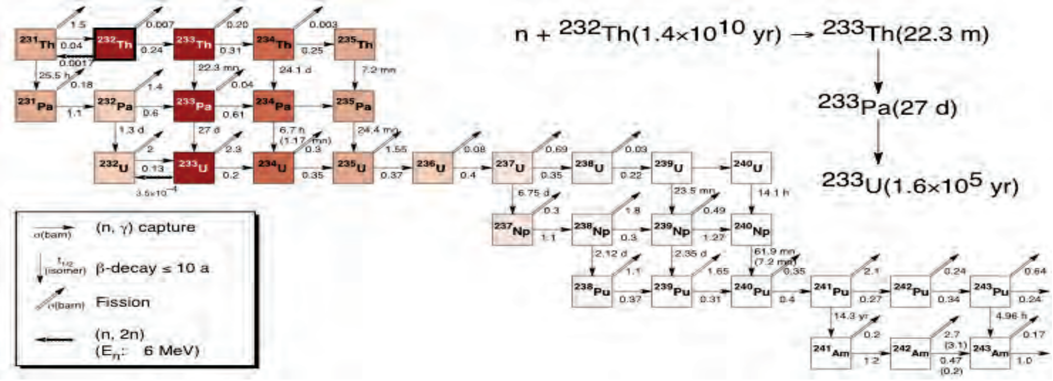


Figure 3. The thorium chain



Thorium

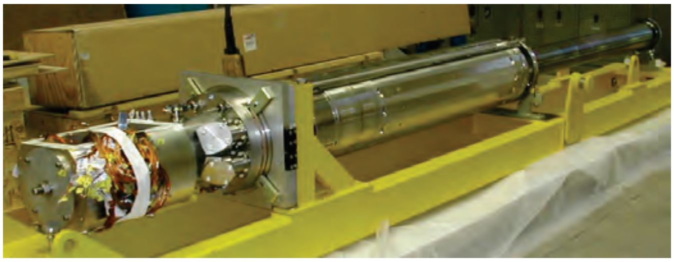
Thorium resources are more abundant than uranium and mainly located in politically stable countries (India, US, Australia, Norway, etc.). They ensure a reliable supply of electric power, independent of weather fluctuations, without releasing greenhouse gas emissions and with minimal impact on the landscape. In addition, used in an ADS, thorium would greatly facilitate a wider use of renewable energy, by ensuring a source of electrical power that can be modulated and is continuously available.

Competitive advantages of Switzerland

The policy of Switzerland, which accounts for only one thousand of the world's population, will have little influence on the energy balance of the entire planet. However, Switzerland, one of the richest and more technologically advanced countries, is in a position to contribute significantly to the development of new solutions to the energy problem by encouraging innovation. The results of the “EU stress test” of the existing Swiss nuclear power plants show the advantage of being ahead of other countries from a technological point of view. The European Parliament took action to implement the required improvements at considerable cost, whereas Switzerland, due to a higher and internationally recognised level of security, is already at the stage of implementing simpler yet adequate measures.

Switzerland has unique strengths in a number of areas directly related to the basic elements of an ADS system for the destruction of nuclear waste. First, the Paul Scherrer Institute (PSI) in Villigen has developed a cyclotron with a proton beam whose characteristics and power have the capacity to drive a nuclear waste incinerator. In January 2007, PSI managed a pioneering experiment with the operation of a high-power neutron spallation source; MEGAPIE [3] (see Figure 4).

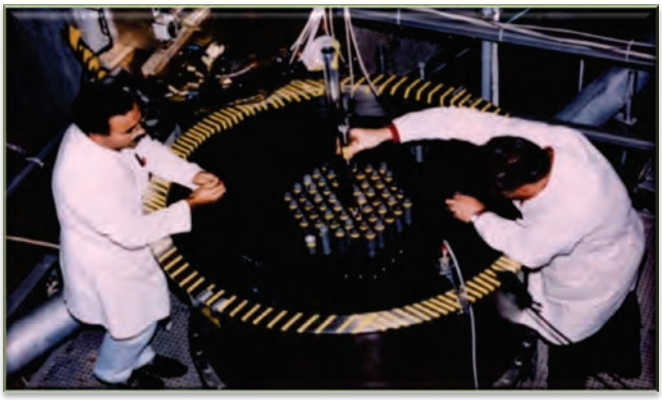
Figure 4. MEGAPIE Target in transport dolly prior to vertical integration at PSI



With a proton beam power in the order of one megawatt, such a neutron source would be sufficient to eliminate about 30 kg of plutonium and minor actinides per year. The PSI also employs many specialists in nuclear safety, which, in the context of the Swiss nuclear withdrawal, could be redeployed, using their expertise for the elimination of the existing waste inventory and for evaluating the safety aspects of the thorium chain.

The presence of CERN in Switzerland is also an important asset because it is at CERN that the founding experiments of an ADS were performed; notably FEAT (see Figure 5) and TARC by Carlo Rubbia and his team. The "n-TOF" installation is also available at CERN for measuring the neutronic characteristics of materials, a knowledge which is necessary for the optimisation of any new nuclear system. Technologies for a new nuclear reactor free from the danger of nuclear accidents, which minimises waste and does not emit CO_2, should be an acceptable choice for the society.

Figure 5. FEAT target at CERN



The iThEC Programme

ADS provides a way of eliminating long-lived waste, mainly in the form of transuranic elements. The method not only transforms these elements into stable waste products but at the same time provides energy, which would finance all or part of the system (see Figure 6). Evidently, such a project must be approached carefully in order to limit the financial risks. iThEC has, therefore, proposed a three-step approach spanning a decade, consisting, first, in an assessment of the costs, followed by a second part for testing the innovative technologies elements of the system and finishing with a third stage which would lead to the construction of a prototype with sufficient capacity to demonstrate the feasibility of a large-scale Thorium-ADS at a power level of several megawatt.

Figure 6. Schematic of a thorium-ADS for energy production and waste elimination

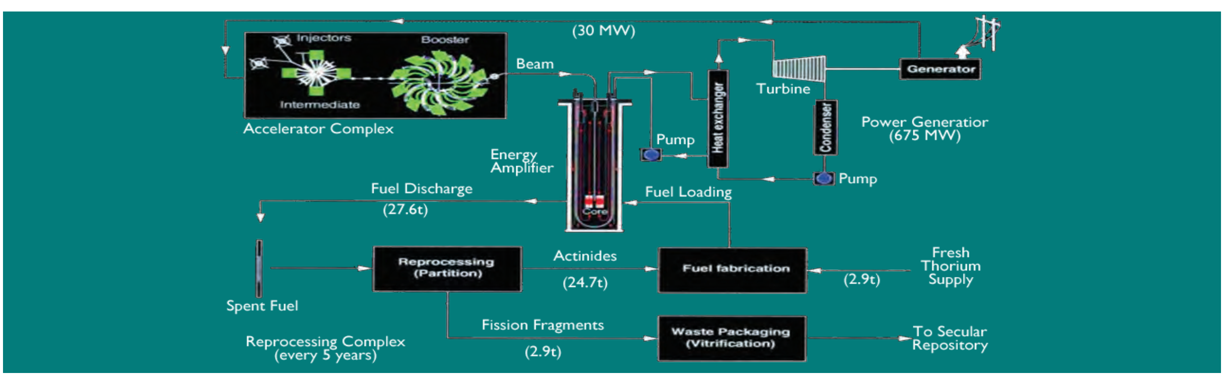


Figure 7. THEC13 conference organised in Geneva by iThEC in October 2013

Conclusion

iThEC [4] proposes that Switzerland undertake, along with other interested parties, a programme on the elimination of nuclear waste through the thorium-ADS concept, taking advantage of synergies with Swiss institutions willing to offer their skills for the rapid implementation of a pilot project. The conference organised by iThEC at CERN in October 2013 will lead global research efforts in thorium-related technologies. This could mark the beginning of a new energy era through international collaboration, an era in which thorium will play a major role along with other new energy sources.

References

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[4] http://www.ithec.org.