Thorium – a Safe Nuclear Fuel

by Trevor Blench, Steenkampskraal Thorium Mine, Western Cape, Souuth Africa

There is growing awareness that thorium is a safe alternative to uranium as a nuclear fuel and that its use will limit nuclear proliferation.

To meet this demand, the Steenkampskraal thorium mine in the Western Cape will begin production in about two years time. The company will mine, process and refine thorium for nuclear fuel applications. The mine has the world's highest-grade rare earth and thorium deposits, with an average rare earths grade of 14,4% and thorium of 2,14%.

HTMR100

Steenkampskraal is also designing a small, low-cost, helium-cooled thorium pebble-bed reactor known as the HTMR100. This will use thorium, mined at Steenkampskraal, as well as Steenkampskraal's locally designed thorium/uranium pebble fuel.

Steenkampskraal is designing the factory to produce the pebble fuel for the HTMR100. The fuel presents no risk of meltdown in the HTMR100 reactor compared to that experienced at Fukushima. Steenkampskraal's strategy covers four key areas: mining thorium and rare earths at Steenkampskraal, designing a safe thorium-based HTMR100 nuclear reactor; designing the thorium/uranium pebble fuel for this new reactor; and testing a safe thorium/uranium and thorium/plutonium pellet fuel for existing reactors.

The TRISO coated-particle pebble fuel for the HTMR100 reactor has been licenced, manufactured and tried and tested over many decades and is proven to be the safest nuclear fuel ever made. Large water reactors are expensive to build and require high-cost

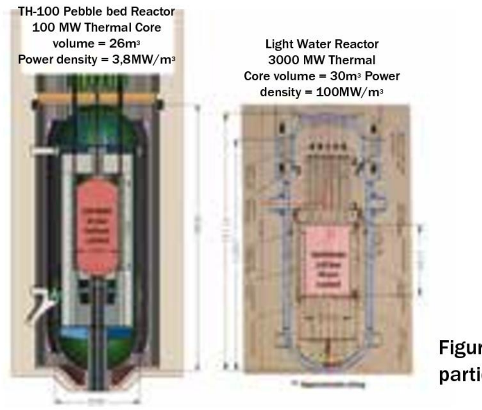

Figure 1: Triso coated-particle pebble fuel.

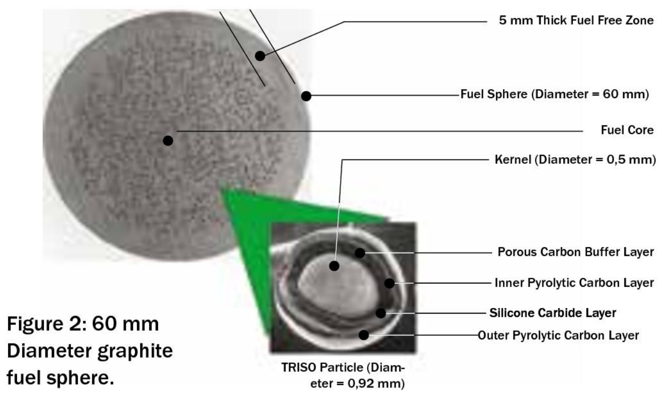

Figure 2: 60 mm Diameter graphite fuel sphere.

distribution networks to deliver the electricity to where it is needed. A small modular reactor will obviate the need to build expensive distribution networks. In addition, the HTMR100 reactor could meet other energy requirements such as desalination.

Present-day nuclear reactors are not suitable for African conditions. They can take years to build and are too large to connect to small and poorly-developed electricity grids.

Benefits

The HTMR100 reactor displays a number of benefits. Firstly, it is small. With a power output of 100 MWth, or about 35 MWe, the HTMR100 could be deployed in countries with a total installed capacity of less than 10 000 MW. It is also suitable for distributed generation. The small reactors could be built at the point where energy is needed, near towns, cities, smelters, factories or mines in remote areas.

Secondly, small HTMR100 modular reactors could be built relatively quickly. Large reactors take up to ten years to build. Small modular reactors, when the supply chain has been established, could be built in two or three years.

Thirdly, large reactors are very expensive and are beyond the financial reach of most African countries. Small modular reactors could be built, like aircrafts, in factories with efficient production capabilities and good quality control, and easily transported to the site. The production of large numbers of small modular reactors could substantially reduce their cost of production.

Tried and tested

The HTMR100 reactor technology has been tried and tested over many years and has proven its safety on many occasions. Because the HTMR100 is a helium-based, gas-cooled reactor, it does not need any water for cooling and could therefore be built away from the sea.

The HTMR100 is also versatile and capable of co-generation of several useful products. It is a high-temperature reactor with outlet temperatures of up to 750 °C. This means that it could supply high-temperature steam for industrial applications, desalinate sea water or purify contaminated water such as acidic mine water. It could also produce clean, safe and reliable base-load electricity. The HTMR100 reactor would have practically no emissions of carbon dioxide or other greenhouse gases. The combination of these factors make the design of the pebble-fuel nuclear reactor a world first. No other nuclear reactor offers a combination of these features contributing to safety, efficiency, environmentally friendly, reduced cost and the elimination of the risk of nuclear proliferation.

In addition to the pebble fuel for the HTMR100 reactor, Steenkampskraal is testing thorium/uranium pellet fuel in co-operation with its associate company in Norway, Thor Energy. This pellet fuel will be used as a supplement for uranium in existing Light Water Reactors (LWRs). Tests are being conducted at the Norwegian government-owned Halden reactor.

There is potential to use this thorium pellet fuel to supplement uranium fuel in approximately 350 existing LWRs around the world with no modifications needed to the

uranium reactor. Thor Energy is now in its fourth year of a five-year test qualification period to produce this world-first commercial thorium/uranium and thorium/plutonium pellet fuel, which will revolutionise the nuclear industry by improving safety and efficiency.

The US, France, Japan, China and South Korea have the most uranium-based nuclear reactors. These are all potential clients for the thorium/uranium pellet fuel. The Korea Atomic Research Institute (KAERI) is one of the organisations working closely with Thor Energy as part of the pellet fuel programme. South Korea has 24 uranium-based nuclear reactors, each the size of Koeberg, representing enormous potential for our pellet fuel.

Thorium fuel can use either uranium or plutonium as the fissile driver material. The by-products produced by thorium are safer than uranium-based fuel that is used in existing nuclear reactors, making thorium environmentally safer and extremely difficult to create a nuclear weapon. Plutonium is now being tested by Thor Energy as an alternative to uranium for producing thorium fuel. This on a large scale would reduce the huge plutonium stockpiles held by some of the world's largest countries.

The thorium fuel cycle is also cleaner than the uranium fuel cycle. Uranium produces plutonium and minor actinides in its waste, and plutonium can be used to manufacture nuclear weapons. The minor actinides produced in existing nuclear reactors remain radioactive for thousands of years. The thorium fuel cycle produces no plutonium and hardly any minor actinides.

The waste from the thorium fuel cycle contains mainly fission products that lose most of their radioactivity in a shorter time period. As a result, the thorium fuel cycle would substantially reduce the problems associated with the management and storage of nuclear waste.

Reactor

STL's HTMR100 (High Temperature Modular Reactor) reactor uses a once-through fuel-cycle process, meaning that the fuel passes through the reactor slower than a traditional high-temperature pebble-bed reactor.

Why is the pebble bed reactor meltdown proof? A pebble bed reactor's core power density is approximately 30 times lower than most water-cooled reactors. Power density is the amount of heat from nuclear fission typically generated in

one cubic metre in the reactor core.

Figure 1 illustrates the size and core volume of a pebble bed reactor producing 1 00 MWt compared to a typical water-cooled reactor which produces 3 000 MWt. The reactor pressure vessels are of similar size (height and diameter) and the cores (ie, the volume where the nuclear fuel is placed to produce heat from nuclear fission) are of similar physical size.

In both cases, a coolant reduces the temperature of the core during normal operation. However, the pebble bed reactor has a number of inherent safety features that ensure that the core cannot melt down when the coolant flow stops, in the case of an accident or some unforeseen event.

The strong negative temperature coefficient, together with the low power density of a pebble bed reactor, means that if the active coolant flow ceases, the reactor will automatically become sub-critical (ie, shut itself down). On the other hand, LWRs also have a negative temperature coefficient, but have a high power density and require active cooling to keep the core cooled, hence the high risk of a meltdown.

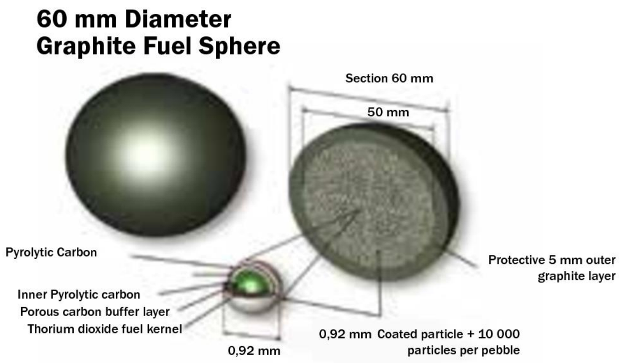

Figure 3: Comparison between Pebble and LWR reactors.

Illustration of Thorium

Conclusion

The British Government published a report in 2014 entitled 'Future Electricity Series Part 3 – Power from Nuclear' which emphasised the importance of small modular reactors and thorium as a nuclear fuel for Britain's future energy supplies.

In addition, the American Nuclear Regulatory Commission published a report in 2014 entitled 'Safety and Regulatory Issues of the Thorium Fuel Cycle' describing the qualification procedures that need to be done in order to introduce the thorium fuel cycle.

About the author

Trevor Blench has worked in financial services for most of his career as a commodity trader, stockbroker, bond trader, foreign exchange trader, financial analyst and portfolio manager. He was a member of the Johannesburg Stock Exchange for many years. He is also a director of Thor Energy AS in Norway. This company commenced a project to develop thorium as a nuclear fuel for Light Water Reactors in 2006. He has a BA Economics, MA in International Relations and an MBA Enquiries: David Boyes. Tel. +27 (0) 12 667 2141 david.boyes@thorium100.com