South Africa's Nuclear Model

A small and innovative reactor is seen as the model for new electricity plants. The project is nearing the starting blocks.

by Tom Ferreira

Although nuclear power generation has by far the best safety and environmental record of any technology in general use, it has for many years been unable to make any meaningful inroads into the wall of negative perceptions that have arisen against it.

But sentiments are changing rapidly on a global scale. The flare-up of oil prices is a sobering reminder of the volatility in the energy market, the exhaustibility of fossil fuels and the urgent need for stable, reliable, non-polluting sources of electrical power that are indispensable to a modern industrial economy.

Today, new types of nuclear plants are prized, and South Africa is moving ahead. The State energy provider, Eskom, is internationally regarded as the leader in the field of the Pebble Bed Modular Reactor (PBMR) technology, a "new generation" nuclear power plant.

A decision on the PBMR project's future is on the near horizon *(see box, The PBMR Nears the Starting Blocks.)* Should approvals be received in the coming months to proceed to the project's next phase, construction of the PBMR demonstration plant will start in 2006, in which case the reactor will start in 2010 and handed over to the client, Eskom, in 2011. Eskom has conditionally undertaken to purchase the first commercial units.

Pebble bed reactors are small, about one-sixth the size of most current nuclear plants. Multiple PBMRs can share a common control center and occupy an area of no more than three football fields.

More specifically, the PBMR is a helium-cooled, graphite-moderated high temperature reactor (HTR). The concept is based on experience in the UK, United States and particularly Germany where prototype reactors were operated successfully between the late 1960s and 1980s. Although it is not the only high-temperature, gas-cooled nuclear reactor being developed in the world, the South African project is internationally regarded as a frontrunner. The South African PBMR includes unique and patented technological innovations which make it particularly competitive.

Mr. Nic Terblanche, Chief Executive of PBMR (Pty) Ltd, says that the commercial reactors would be sized to produce about 165-MWe each. To maximise the sharing of support systems, the PBMR has been configured into a variety of options, such as an 8-pack layout. "This is the most cost effective layout and allows the modules to be brought on line as they are completed," he says.

The concept allows for additional modules to be added in accordance with demand and to be configured to the size required by the communities they serve. It can operate in iso-

The PBMR Nears the Starting Blocks

South Africa's Eskom has two partners in the PBMR project, namely the Industrial Development Corporation (IDC), and British Nuclear Fuels. The partners have all expressed a desire to proceed to the detailed design and construction phase. This phase involves construction of a demonstration reactor at Koeberg near Cape Town and an associated fuel plant at Pelindaba near Pretoria, where fuel for Koeberg used to be manufactured.

So far, the project's detailed feasibility study, basic design and business case have been completed and the project team is ready to move to the construction phase once the various approvals are received.

Eskom is currently awaiting the final verdict on the Environmental Impact Assessment (EIA) from the Minister of Environmental Affairs and Tourism (DEAT) following an initial positive Record of Decision (RoD) on the EIA reports in June 2003. The DEAT found the project was, with some conditions, acceptable from an environmental impact point of view.

Subsequent to the positive RoD, interested and affected parties were granted two months to lodge appeals with the Minister of Environmental Affairs and Tourism. The appeal period ended in August 2003 and the Minister is currently reviewing the appeals.

In addition to the final verdict on the EIA and approval by the investors, proceeding to the next phase (building of a demonstration module and fuel plant), is still subject to the issuing of a construction license by the South African National Nuclear Regulator and approval by the South African Government.

The project seems to be strongly supported by President Thabo Mbeki and his government. In fact, a South African delegation led by the Department of Trade and Industry met with senior executives of Areva and Framatome in Paris earlier this year to negotiate possible French participation in the project. Areva is one of several international companies who have shown an interest in getting involved in the US $13 billion project.

Design view of the PBMR module concept.

lation anywhere, provided that there is sufficient water for cooling. Dry cooling, although more expensive, is an option that would provide even more freedom of location.

Developments Marking Progress

An exciting new development is PBMR (Pty) Ltd's intention to submit a proposal for the US$ 1.1-billion hydrogen production project at the Idaho National Environmental and Energy Laboratory in the USA. The hydrogen initiative calls for a plant that can generate both electricity and high temperature process heat. Initial conceptual layouts show that, with minor modifications, the current PBMR power plant can meet this requirement.

Participation in the hydrogen project offers clear benefits that can act as a catalyst for the early commercialization of the PBMR technology in the USA. This would lead to the reactor becoming the preferred route as far as HTR technology is concerned.

The PBMR concept is based on the philosophy that new reactors should be small. The reactor consists of a vertical steel pressure vessel lined with graphite bricks. It uses silicon carbide coated particles of enriched uranium oxide encased in graphite to form a fuel sphere or pebble, each containing about 15,000 uranium dioxide particles. Helium is used as the coolant and energy transfer medium.

The project achieved a major engineering milestone with the successful starting up of a test rig of the PBMR power conversion system. The test rig represents the first closed-cycle, multi-shaft gas turbine in the world. The model was designed and built by the Faculty of Engineering at Potchefstroom University near Johannesburg, with technical input from the PBMR project team.

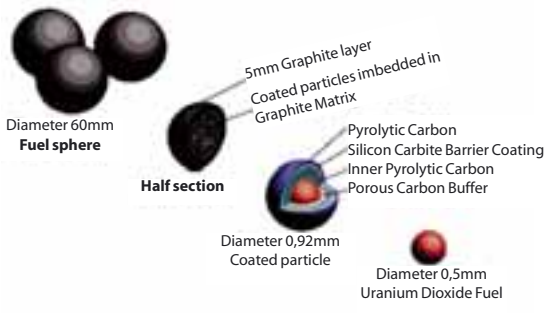
The South African Nuclear Energy Corporation, which is under contract from PBMR (Pty) Ltd to develop the fuel manufacturing capability, is in the meantime making good

progress. Its focus is on developing the exacting production techniques required for the manufacture of complete fuel spheres.

Demonstrating Safety

The design's fundamental concept is aimed at achieving a plant having no physical process that could cause a radiation hazard beyond the site boundary. In addition, the peak temperature reached in the core during the transient is not only below the demonstrated fuel degradation point, but also far below the temperature at which the physical structure is affected. This will preclude any prospect of a core melt accident.

The safe design was proven during a public and filmed plant safety test at the German AVR power plant, on which the PBMR reactor core concept is based. The Germans stopped



The uranium fuel spheres or pebbles are 60 mm in diameter, which is slightly smaller than a tennis ball. On the right are the coated particles, which are abouts 1mm in diameter. A coated particle consists of a kernel of uranium dioxide surrounded by four coating layers.

the flow of coolant through the reactor core and left the control rods withdrawn just as if the plant was in normal power generation mode.

It was demonstrated that the nuclear reactor core shut itself within a few minutes. It was subsequently proven that there was no deterioration over and above the normal design failure fraction of the nuclear fuel. This proved that a reactor core meltdown was not credible and that an inherently safe nuclear reactor design had been achieved.

"We're trying to change the nuclear culture," says Phumzile Tshelane, General Manager Corporate Services of PBMR (Pty) Ltd. "If the PBMR demonstration module proves to be technically and commercially viable, it could dramatically boost the prospects of nuclear energy on a global scale, fulfilling at last the dream of a non-polluting power source that is safe, competitive and perhaps even popular."

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Joining Forces for Innovation

South Africa already operates two conventional nuclear power plants at Koeberg, which together supply about 6% of the country's electricity, including most of nearby Cape Town's needs. Electricity demands are expected to keep rising in years ahead. About 60% of South Africans today have access to electricity, compared to 30% a decade ago. Nuclear and renewable sources of energy helped fuel the growth, though coal remains the dominant power source, generating 90% of all electricity.

Pebble bed reactors are not new to the nuclear world, though technological innovations now are helping to bring them to market. If built, South Africa's PBMR would be the largest commercial example of the technology.

Both Germany and China have developed PBMRs, and research and development is intensifying in the United States, China and other countries. Recently, researchers at the Massachusetts Institute of Technology (MIT) in the US and Tsinghua University in Beijing, China formed a partnership to collaborate on PBMR development under an international agreement between the US Department of Energy and the China Atomic Energy Authority.

For the past six years, MIT and Tsinghua research teams have been working independently on studies of the reactor. Their joint work now sets up ways for the research teams to exchange technologies and ideas.

"The agreement provides an incredible opportunity for bringing the world together on this promising technology," says Professor Andrew Kadak of the Department of Nuclear Engineering, who leads the MIT research and was instrumental in the three-year effort to get the agreement signed. He is now contacting other pebble-bed researchers in the United States, Europe, South Africa and elsewhere to develop mutual topics of interest. The aim is to form an international effort that will go far beyond the MIT/Tsinghua collaboration and build on worldwide interest in the technology.

One focus of interest is a "plug-and-play" approach to building components of pebble bed reactors. If competitive, researchers say such small, modular plants will be attractive not only to the US market but also to China and other rapidly developing countries that have widely dispersed populations.