THE PEBBLE BED EVOLUTION

The PBMR is based on the designs originally developed in an extensive German development programme.

The Germans researched high temperature reactors (HTR), and built a 15 MWe (40 MW thermal) AVR research reactor at the nuclear research centre in Jülich. It was planned, constructed and operated as a reactor experiment on an industrial scale and was intended to furnish an originally German contribution to the development of economic nuclear power on the basis of "first-of-a-kind" technology. It operated from 1966 to 1988, when it was decommissioned due to political considerations and because it had fulfilled all planned research experiments.

The main feature of the AVR was a high coolant temperature to allow the generation of steam conditions and correspondingly high plant efficiencies usually reached in modern fossil fueled steam power plants. The high steam temperatures were possible due to the use of ceramic fuel and the graphite that was used as fuel structure and moderator as well as core structure material. Spherical fuel elements were used and fueling was done with the reactor in operation.

The AVR was used to test different designs of fuels, fuel loading systems and safety systems. In spite of the test programmes and despite being a first prototype, it produced power for 70 percent of its life. During its 22 years of operation, the design proved the superior behaviour of the coated particle concept, the favourable safety characteristics of the core and even fulfilled the safety requirements listed today for future reactors in terms of the control of improbable events.

The results of various tests performed on the reactor and operational records assist in the validation of numerous analyses performed for the design and safety demonstration of the PBMR.

Design changes made to the AVR resulting from operating experience were incorporated in the design of the 300 MWe (750 MWth) thorium high-temperature reactor (THTR), which operated between 1985 and 1988. The THTR was a first-of-its-kind production plant intended to demonstrate the viability of the different subsystem hardware designs, with specific emphasis on plant availability and maintainability. To this end, the design concentrated on building a plant with a lifetime of 40 years and an availability of 80 to 90 percent. The THTR-300 was going to be the front-runner of a commercial machine, namely the HTR-500.

Although both the AVR and the THTR-300 were pebble bed reactors, there were fundamental engineering differences because of the differences in size. The THTR had a re-enforced concrete pressure vessel, a much larger core diameter (2,5m to 5m), control rods in the reflector and shutdown rods in the pebble core.

These changes were largely driven by the presumed need for larger reactor power levels. The concrete pressure vessel led to difficulties in insulation of the low temperature concrete (limit 60 ºC or 140 ºF) from the high temperature gases (650 ºC or 1 202 ºF). In addition, the in-core control rods caused damage to fuel elements because of the need to insert the control rods into the pebble bed by force during the initial testing period. The resulting high scrap level in the fuel system, combined with too high helium flows, led to initially low availability of the fuel handling system.

Despite these and other technical deficiencies, the THTR-300 achieved the following milestones:

- first nuclear power on 6 September 1985;
- first power into the grid on 16 November 1985;
- 100 percent power performance on 23 September 1986;
- handover to the utilities' consortium (HKG) on 1 June 1987.

Based on the experience gained from the AVR and the THTR, two German-based groups developed further pebble bed reactor designs ranging from high power reactors mainly developed by ABB (previously Brown Boveri) to the modular inherently safe design of Siemens Interatom. These two groups later combined to form Hochtemperatur Reaktorbau GmBh.

Siemens was in the process of negotiating orders for several reactors from the then East German government, the USSR and a large German chemical company when, in 1989, the Berlin wall fell. As a result, all the potential buyers for Modul reactors broke off negotiations.

Siemens subsequently decided to stop further work. At the same time, the West German government came under pressure to close existing nuclear plants. It was easier to close down the HTR research reactors, which had no impact on the electricity supply to Germany, than existing commercial nuclear power stations. In the years that followed, the collapse of the USSR and the reunification of Germany placed constraints on the budgets for further reactors.

In 1999, Eskom obtained the right to access the HTR engineering database that includes details of the Siemens/Interatom HTR-Modul design. This design can be regarded as the forerunner of the PBMR as an inherently safe reactor.

The PBMR core design was made using the same design philosophy as was used in the design of the HTR-Module. A concept license was issued for this reactor and the safety arguments used in the HTR-Module safety application are relevant for the PBMR safety case.

Many components used in the fuel handling and control systems of the PBMR are copies of those used in the THTR programme. It includes all the improvements made over the years, thus saving a lot of costly development work.

The PBMR concept also includes the technological advances made in gas turbine technology since the 1980s. The small plant size and the elimination of a steam cycle both contribute to the achievement of a plant configuration with a very robust safety case.

The fuel design of the PBMR falls within the qualified fuel design parameters of the German fuel programme. The actual fuel design is that specified for the Interatom Modul reactor design, which was qualified and received provisional certification in Germany.